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Related to the Silicate Industries

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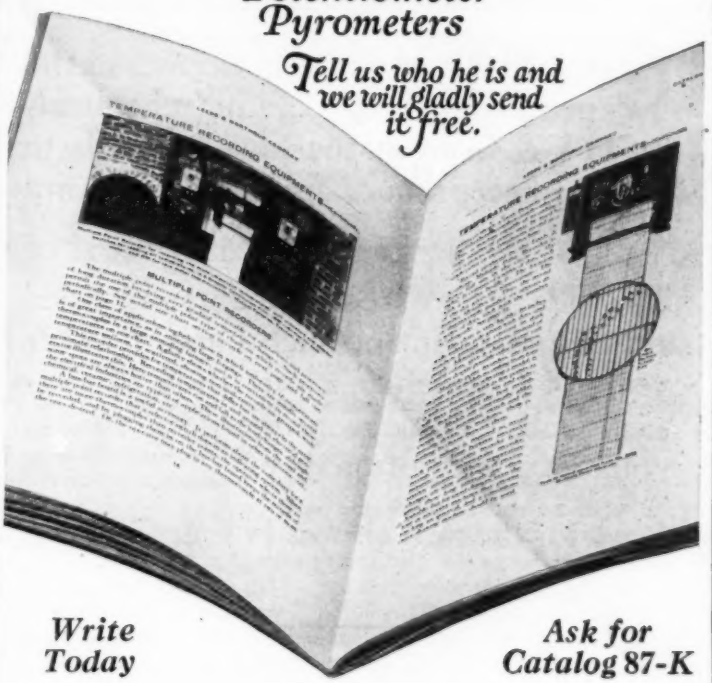

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SOME FACTORS INFLUENCING THE RATE OF PICKLING OF SHEET IRON[1]

BY J. E. HANSEN AND G. S. LINDSEY[2]

ABSTRACT

Experiments with regard to various factors entering into pickling of sheet iron show that: (1) a freshly made sulphuric acid pickling bath pickles faster than a bath in which there is any concentration of ferrous sulphate and that (2) there is no evident advantage in adding a portion of old pickling solution to a new pickling solution "to get it to work right," although practical experience indicates otherwise; (3) increased ferrous chloride concentration in a muriatic acid pickling bath increases the rate of pickling; (4) ferric sulphate in a sulphuric acid bath will accelerate the rate of pickling, but will soon change to ferrous sulphate and then retard the rate; (5) decrease in acidity from usual strength decreases rate of pickling; (6) increase of temperature of bath accelerates rate of pickling; (7) iron annealed just previous to pickling loses 250–400% more in pickling than unannealed iron; (8) use of monel metal basket accelerates the rate of pickling due to electrochemical reactions; and (9) use of muriatic acid or sodium chloride in mixtures with sulphuric acid retards the rate of pickling.

Introduction

This is a study of the effect on the rate of pickling of the varying factors which may and do exist in the acid bath in which sheet iron is pickled.

[1] Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Atlanta, Ga., Feb., 1926. (Enamel Division.)

[2] Industrial Fellows, Mellon Institute of Industrial Research, Univ. of Pittsburgh, Pittsburgh, Pa.

In either a muriatic or sulphuric acid pickling bath the concentration of acid and the temperature of the bath may be varied at will, and with use there develops an increasing concentration of iron salts. These three variables, together with the condition of the metal itself and other external factors affecting the pickling process have been given consideration in this work.

Method of Procedure

Test pieces of 22-gage Armco Iron, 1 inch wide and 6 inches long, in duplicate, were used in this work. Glass beakers containing two liters of pickling solution were the pickling tanks, and these were placed in a thermostatically controlled water bath to insure even heating and a constancy of temperature of $\pm 2°F$ during the experiment. The ratio of amount of acid present against area of iron exposed to be pickled was large enough to insure but little diminution of acid strength during the pickling time.

The loss of weight of the various samples was considered indicative of the rate of pickling or rate of attack of acid on the iron. All samples of iron were weighed before and after annealing (if annealed), and, after each pickling, were washed in water, alcohol, and ether, then dried and weighed.

Acid strength and iron concentration of each pickling bath was determined by titration with standard sodium hydroxide and permanganate solutions. Results in grams strength per 100 cc. of solution are referred to in the data as per cent by volume.

Iron in solution in the pickling acid was calculated as per cent of iron, and not as per cent of ferrous sulphate or ferrous chloride, as the case might be.

The majority of all data on pickling with sulphuric acid were determined at 130°F, which may be somewhat lower than most commercial practice, but this was the most practical temperature at which to run the constant temperature bath over a long period of time.

TABLE I

ANNEALED SHEETS

Dissolved iron in bath (%)	Gain in annealing	Loss initial 7½ min. period (gms.)	Total loss in 15 min. period (gms.)	Total loss in 30 min. period (gms.)	Total loss in 60 min. period (gms.)	Loss 7½–15 min. period (gms.)	Loss 7½–30 min. period (gms.)	Loss 7½–60 min. period (gms.)
0.0	.0187	.1550	.1620	.1682	.1790	.0070	.0130	.0240
5.16	.0205	.1775	.1825	.1880	.1990	.0050	.0105	.0215
8.18	.0195	.1195	.1245	.1295	.1385	.0050	.0100	.0190
16.40	.0210	.1365	.1385	.1430	.1500	.0020	.0065	.0135

Experimental Data

The first experiment was with sheets annealed at 1300°F for one and one-half minutes and pickled at 130°F in 6.1% sulphuric acid baths of various concentrations of iron sulphate.

The average loss in grams per sample is shown in Table I, and in Fig. 1.

The loss during the initial pickling time of 7½ minutes varies over quite a wide range, but this is due not so much to the concentration of chemicals in the bath as to the varying amount of the scale of iron oxide formed on the sheets during the annealing process. The curves in Fig. 1 fall in no regular order, due to this varying amount of scale on the samples, and the relative slope of the curves through the remaining pickling intervals is hard to interpret. However, in plotting the loss in weight of samples after the original 7½ minutes pickling time (see lower portion of Fig. 1) the curves arrange themselves in a regular order, clearly indicating that with increasing percentage of iron in the bath, the attack of acid on the metal is lessened.

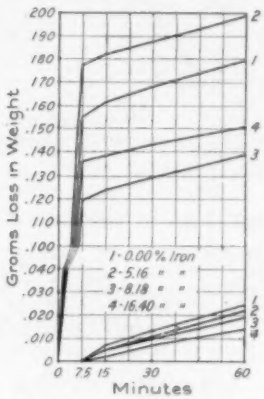

FIG. 1.—Shows actual grams loss in weight of annealed sheets pickled in 6.1% sulphuric acid at 130°F. Lower set of curves shows loss in weight after initial 7½ min. pickling period, and therefore shows relative effects of different iron concentrations of bath.

Since the whole curve starting from zero minutes is hard to interpret, and since the curve starting at 7½ minutes indicates the effect of the variable factor, only the latter or interpretable portion of the data will hereafter be plotted.

I. Effect of Ferrous Sulphate

Table II and Fig. 2 show the effect of increasing concentration of dissolved iron in the bath, and indicate the relative rates of attack of the pickling solutions on both annealed and unannealed sheets, pickled in 6.1% sulphuric acid at 130°F.

TABLE II

	Unannealed			Annealed		
Dissolved iron in bath (%)	Loss 7½–15 min. period (gms.)	Total loss 7½–30 min. period (gms.)	Total loss 7½–60 min. period (gms.)	Loss 7½–15 min. period (gms.)	Total loss 7½–30 min. period (gms.)	Total loss 7½–60 min. period (gms.)
0.0	.0080	.0232	.0485	.0070	.0130	.0240
5.16	.0065	.0185	.0390	.0050	.0105	.0215
8.18	.0050	.0160	.0350	.0050	.0100	.0190
16.40	.0045	.0140	.0305	.0020	.0065	.0135

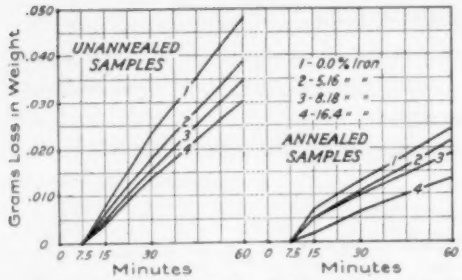

FIG. 2.—Shows relative loss in weight of samples pickled in 6.1% sulphuric acid at 130°F, varying the amount of dissolved iron in the bath.

These curves show that with increasing iron concentration in the bath (acidity and temperature constant) there is a progressive decrease in the loss of weight or in the rate of pickling of the metal.

The action of the acid on the metal during the $7\frac{1}{2}$-minute to 60-minute period is less in the case of annealed iron than in the case of unannealed iron, indicating that there is less danger of overpickling the former.

There is no great difference in the slope of these curves to indicate any certain concentration of iron salt in the bath above which pickling action is slowed down to a marked degree, but by referring to the curves for unannealed sheets it can be noted that when 8.18% dissolved iron is present the rate of pickling is 28% less than with no iron present, and with 16.4% dissolved iron present the pickling rate is 37% less than with no iron present.

II. Effect of Addition of Old Pickle Solution to Fresh Acid

Since it is the practice in some pickling departments to add a portion of old pickle solution to a fresh tank of acid to "get it to work right," one part of old pickling solution analyzing 9.644% ferrous iron, 0.133% ferric iron, and 6.1% sulphuric acid was added to 4 parts of fresh 6.1% sulphuric acid pickling solution.

This results in a 6.1% sulphuric acid bath, containing 1.93% ferrous iron and 0.027% ferric iron.

The rate of pickling in this bath, at 130°F, is shown in Table III and Fig. 3.

TABLE III

Solution	Unannealed			Annealed		
	Loss $7\frac{1}{2}$–15 min. period (gms.)	Loss $7\frac{1}{2}$–30 min. period (gms.)	Loss $7\frac{1}{2}$–60 min. period (gms.)	Loss $7\frac{1}{2}$–15 min. period (gms.)	Loss $7\frac{1}{2}$–30 min. period (gms.)	Loss $7\frac{1}{2}$–60 min. period (gms.)
Fresh acid	.0080	.0232	.0485	.0070	.0130	.0240
Fresh acid plus 20% old pickle solution	.0060	.0195	.0405	.0070	.0130	.0255

The data indicate the lessened rate of pickling of unannealed sheets, and approximately the same rate of pickling of annealed sheets when old pickle solution is added to the fresh acid, as compared to the action of the fresh acid itself.

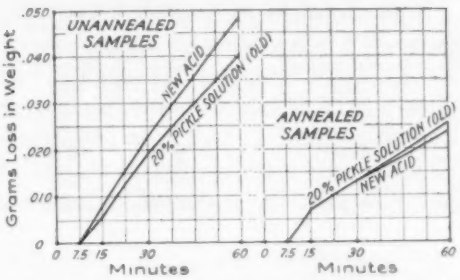

FIG. 3.—Shows effect of adding 20% of old sulphuric acid pickle solution to new pickling bath of sulphuric acid. Samples pickled at 130°F.

To determine what effect the ferric or oxidized iron salts of the old pickle solution might have on the activity of the pickling bath, ferric sulphate equivalent to a concentration of 0.4% ferric iron was added to a 6.1% fresh sulphuric acid bath and sheets were pickled at 130°F, with results as shown in Table IV and Fig. 4.

TABLE IV

Solution (%)	Unannealed Loss 7½–15 min. period (gms.)	Unannealed Loss 7½–30 min. period (gms.)	Unannealed Loss 7½–60 min. period (gms.)	Annealed Loss 7½–15 min. period (gms.)	Annealed Loss 7½–30 min. period (gms.)	Annealed Loss 7½–60 min. period (gms.)
6.1 sulphuric acid plus 0.4 ferric iron	.0255	.060	.123	.0135	.0475	.1035
6.1 sulphuric acid	.0080	.0232	.0485	.0070	.0130	.0240

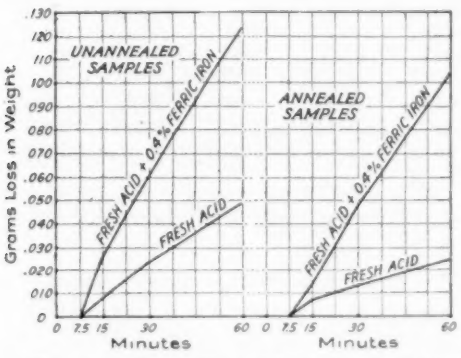

FIG. 4.—Shows effect of ferric iron dissolved in sulphuric acid pickling bath.

These curves demonstrate the accelerating effect of ferric iron in the pickle solution, which is in line with the already known corroding effects of ferric salts. The curves are presented merely as a matter of interest, because ferric salts have little to do with present day pickling practice, since they are reduced to ferrous salts by the nascent hydrogen generated in the pickling operation and would hence exist for only a short time after addition.

III. Effect of Variation in Acid Strength

A lowering in strength of acid shows a decrease in the rate of pickling, as would be expected. The relative decrease is shown in Table V and Fig. 5, using sulphuric acid at 130°F.

TABLE V

Strength sulphuric acid	Unannealed Grams loss 7½–15 min. period	Unannealed Grams loss 7½–30 min. period	Unannealed Grams loss 7½–60 min. period	Annealed Grams loss 7½–15 min. period	Annealed Grams loss 7½–30 min. period	Annealed Grams loss 7½–60 min. period
4.60%	.0085	.0220	.0430	.0050	.0120	.0185
5.55%	.0085	.0255	.0525	.0055	.0130	.0195
6.54%	.0095	.0290	.0555	.0065	.0155	.0265

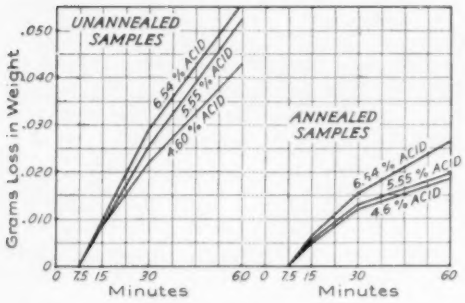

FIG. 5.—Shows relative pickling loss at 130°F, using different strengths of sulphuric acid.

This decrease in the rate of pickling due to lessening acid concentration is not, however, of as much effect as change in pickling temperature, as will be shown below.

IV. Effect of Temperature of Acid

To determine the relative effect of difference in temperature upon the rate of pickling, four trials were run, using fresh 6.1% sulphuric acid at 130°F, 150°F, 170°F, and at 190°F. The results of these trials are shown in Table VI and Fig. 6.

TABLE VI

Temperature °F	Unannealed Loss 7½–15 min. period (gms.)	Unannealed Loss 7½–30 min. period (gms.)	Unannealed Loss 7½–60 min. period (gms.)	Annealed Loss 7½–15 min. period (gms.)	Annealed Loss 7½–30 min. period (gms.)	Annealed Loss 7½–60 min. period (gms.)
130	.0080	.0232	.0485	.0070	.0130	.0240
150	.0110	.0350	.0740	.0105	.0250	.0500
170	.0205	.0590	.1670	.0165	.0380	.0840
190	.0320	.0930	.2355	.0275	.0745	.1975

It is interesting to note in these curves the rapid rise in the rate of pickling due to increase in temperature of the solution, and by comparison with the curves in Fig. 5 it will be noted that an increase in the temperature of 20°F will more than compensate for a 2% decrease in acidity of the solution. This fact is, of course, made use of in "killing" a pickling solution before draining the tank.

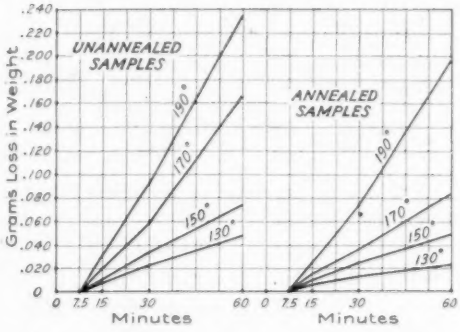

FIG. 6.—Shows relative pickling loss, using fresh 6.1% sulphuric acid at different temperatures.

V. Effect of Dissolved Iron (Ferrous Chloride) in Muriatic Acid

Changing from sulphuric acid to muriatic acid, we used a pickling solution of one part 20°Bé muriatic acid and two parts of water at 85°F (approximately room temperature). This acid analyzed 11.45% hydrochloric acid (114.5 grams HCl per liter), and with increasing ferrous iron concentration in the bath (acidity and temperature constant) we find that the rate of pickling increases, as is shown in Table VII and Fig. 7.

TABLE VII

Ferrous iron content of 11.45% muriatic acid solution (%)	Unannealed		Annealed	
	Loss 15–30 min. period (gms.)	Loss 15–60 min. period (gms.)	Loss 15–30 min. period (gms.)	Loss 15–60 min. period (gms.)
0.00	.0040	.0100	.0050	.0090
2.80	.0050	.0135	.0045	.0125
5.29	.0065	.0155	.0060	.0150
7.57	.0060	.0155	.0055	.0140
10.24	.0075	.0235	.0085	.0175
12.40	.0120	.0275	.0105	.0220
15.26	.0140	.0390	.0110	.0275
18.84	.0130	.0365	.0130	.0330

TABLE VIII

6.1% sulphuric acid, 130°F		11.45% muriatic acid, 85°F	
Iron in soln. (%)	Loss, 45 min. pickling (gms.)	Iron in soln. (%)	Loss, 45 min. pickling (gms.)
0.00	.0405	0.00	.0100
0.45	.0330	2.80	.0135
1.05	.0295	5.29	.0155
2.04	.0305	7.57	.0155
5.16	.0325	10.24	.0235
8.18	.0300	12.40	.0275
12.55	.0245	15.26	.0390
16.40	.0260	18.84	.0365

In this case, using cold muriatic acid, we used an initial pickling period of 15 minutes to remove the varying amount of scale on each sample sheet, and based our conclusions on the rate of pickling during the succeeding pickling intervals up to one hour.

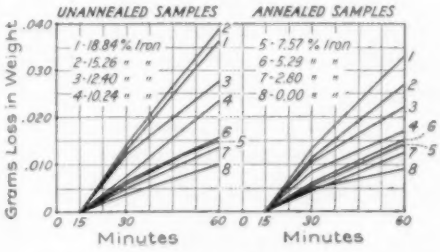

FIG. 7.—Shows effect (grams loss) of varying dissolved iron concentration in 11.45% muriatic acid at 85°F.

The increase in the rate of pickling with increase in ferrous iron concentration in hydrochloric (muriatic) acid, is the reverse of what we found in sulphuric acid, where increasing iron concentration lowered the rate of

pickling. This is illustrated in Table VIII and Fig. 8, where total loss during the entire pickling period is plotted against concentration of ferrous iron, both in sulphuric and muriatic acid solution.

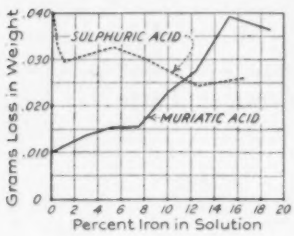

FIG. 8.—Shows effect (grams loss during 45 minutes pickling) of increasing dissolved iron concentration in pickling baths of sulphuric acid at 130°F and muriatic acid at 85°F.

No variations in acid strength or temperature were made with muriatic acid, as with sulphuric acid, but Conroy[1] found that the rate of pickling in less than 20% hydrochloric acid diminished but slightly with decrease in acidity, and that with each increase in temperature of 10°C (18°F) the rate of pickling doubled. This statement seems to be fairly well borne out in practice.

VI. Comparative Pickling Loss—Unannealed and Annealed Metal

In Table IX and Fig. 9, we have averaged all experimental determinations covered in the preceding data, to compare the total loss in weight of unannealed and annealed metal in the pickling process.

TABLE IX

Solution, 6.1% sulphuric acid at 130°F Dissolved iron content = 5.73% (calculated as av.)			Solution, 11.45% muriatic acid at 85°F Dissolved iron content = 9.05% (calculated as av.)		
Pickling time (minutes)	Loss unannealed sheets (gms.)	Loss annealed sheets (gms.)	Pickling time (minutes)	Loss unannealed sheets (gms.)	Loss annealed sheets (gms.)
7½	.0304	.1397			
15	.0364	.1446	15	.0497	.1733
30	.0479	.1504	30	.0582	.1813
60	.0672	.1594	60	.0723	.1921

These curves show the rapid loss in weight during the first few minutes of pickling, while the acid is attacking the scale and rust on the metal and the lessened attack during the succeeding minutes of pickling time.

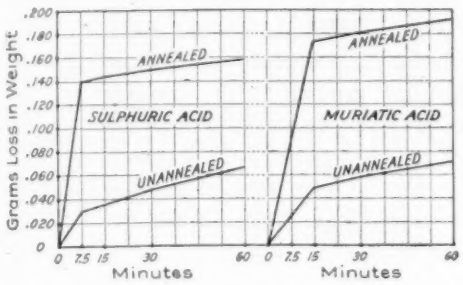

FIG. 9.—Shows comparative pickling loss of annealed and unannealed sheets in sulphuric acid at 130°F and in muriatic acid at 85°F.

VII. Influence of Monel Metal Basket

In the preceding experiments, all metal samples

[1] *Jour. Soc. Chem. Ind.*, **20**, 316–20 (1901).

were simply immersed in the pickling solution in a glass beaker, so in order to approximate plant conditions more closely, where the ware to be pickled is usually placed in a basket of acid-resisting metal, other trials were made in which our samples were placed in a monel metal basket for pickling.

It is interesting to note that our samples in this case all lost more weight, *i.e.*, pickled faster, when using the monel metal basket than when they were in contact only with the glass surface.

Table X and Fig. 10 show the comparative loss in weight of unannealed iron pickled in muriatic acid, using the monel metal basket and not using it.

A like increase in rate of pickling is found in sulphuric acid at 130°F, using a monel metal basket on either unannealed or annealed sheets, as may be seen from Table XI and Fig. 11.

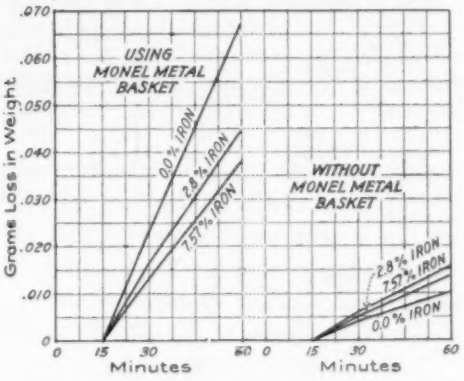

FIG. 10.—Shows rate of pickling in muriatic acid at 85°F when using monel metal basket, compared with rate of pickling without basket.

TABLE X

Ferrous iron content of 11.45% muriatic acid solution (%)	Using Monel Metal Basket: Loss 15–30 min. period (gms.)	Using Monel Metal Basket: Loss 15–60 min. period (gms.)	Without Monel Metal Basket: Loss 15–30 min. period (gms.)	Without Monel Metal Basket: Loss 15–60 min. period (gms.)
0.0	.0230	.0670	.0040	.0100
2.8	.0165	.0445	.0050	.0135
7.57	.0130	.0380	.0060	.0155

TABLE XI

Solution 6.1% sulphuric acid		Unannealed: Loss 7½–15 min. period (gms.)	Unannealed: Loss 7½–30 min. period (gms.)	Unannealed: Loss 7½–60 min. period (gms.)	Annealed: Loss 7½–15 min. period (gms.)	Annealed: Loss 7½–30 min. period (gms.)	Annealed: Loss 7½–60 min. period (gms.)
0.0 % dissolved iron	without monel	.0080	.0232	.0485	.0070	.0130	.0240
	with monel	.0165	.0440	.0870	.0105	.0250	.0485
5.16 % dissolved iron	without monel	.0065	.0185	.039	.0050	.0105	.0215
	with monel	.0115	.0300	.0740	—	—	—

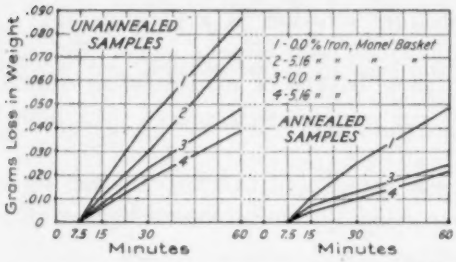

FIG. 11.—Shows comparative rate of pickling of annealed and unannealed sheets in 6.1% sulphuric acid at 130°F, using monel metal basket for samples.

An increase in the rate of pickling, due to the electrolytic potential difference between monel metal and iron, will in all probabilities, also be found at other acid temperatures and concentrations.

VIII. Effect of Addition of Muriatic Acid and of Sodium Chloride To a Sulphuric Acid Pickling Bath

Some few plants in which sheet iron or steel is pickled use mixtures of sulphuric and muriatic acid for their pickling bath, or mixtures of sulphuric acid and sodium chloride (common salt), which reacts with the sulphuric acid to form a mixture of sulphuric acid, muriatic acid, and sodium bisulphate, according to the equation:

$$\text{Excess } H_2SO_4 + NaCl = H_2SO_4 + HCl + NaHSO_4.$$

Both sodium chloride and muriatic acid function as retarders of the action of sulphuric acid on iron, according to O. P. Watts[1] and this is evident from the data presented in Table XII and Fig. 12, where mixtures of muriatic and sulphuric acid (1% muriatic –5% sulphuric and 2% muriatic –4% sulphuric) were used at 130°F.

The retarding effect of the muriatic acid is evident from the curves in Fig. 12, and is all the more evident when we consider that although the total acid percentage composition of our baths are the same, the normality of our solutions increase when we substitute muriatic acid for sulphuric acid and hence our pickling bath is really "stronger."

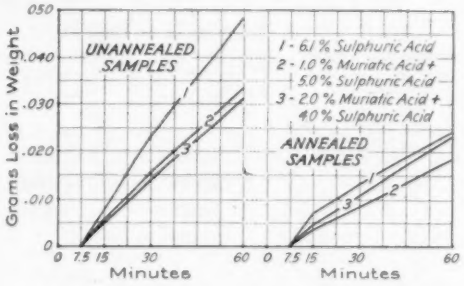

FIG. 12.—Shows retarding effect of muriatic acid in a sulphuric acid pickling bath, as compared to a straight sulphuric acid bath.

In Table XIII and Fig. 13, the effect of adding sodium chloride (common salt) to a sulphuric acid pickling bath is shown.

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[1] *Trans. Am. Elec. Soc.*, **21**, p. 337 ff. (1912).

TABLE XII

Solution	Unannealed Loss during 7½–15 min. period (gms.)	Unannealed Loss during 7½–30 min. period (gms.)	Unannealed Loss during 7½–60 min. period (gms.)	Annealed Loss during 7½–15 min. period (gms.)	Annealed Loss during 7½–30 min. period (gms.)	Annealed Loss during 7½–60 min period (gms.)
1% muriatic acid } 5% sulphuric acid }	.0055	.0155	.0335	.0035	.0085	.0180
2% muriatic acid } 4% sulphuric acid }	.0050	.0140	.0315	.0045	.0105	.0230
6% sulphuric acid }	.0080	.0232	.0485	.0070	.0130	.0240

TABLE XIII

Solution	Unannealed Loss during 7½–15 min. period (gms.)	Unannealed Loss during 7½–30 min. period (gms.)	Unannealed Loss during 7½–60 min. period (gms.)	Annealed Loss during 7½–15 min. period (gms.)	Annealed Loss during 7½–30 min. period (gms.)	Annealed Loss during 7½–60 min. period (gms.)
6.1% sulphuric acid	.0080	.0232	.0485	.0070	.0130	.0240
6.1% sulphuric acid +2.5% sodium chloride	.0055	.0160	.0350	.0050	.0085	.0170
6.1% sulphuric acid +5% sodium chloride	.0055	.0150	.0350	.0060	.0120	.0225

It is quite evident that the addition of sodium chloride to the sulphuric acid bath retards the rate of pickling, and a small amount (2.5%) seems to be more effective than twice that amount.

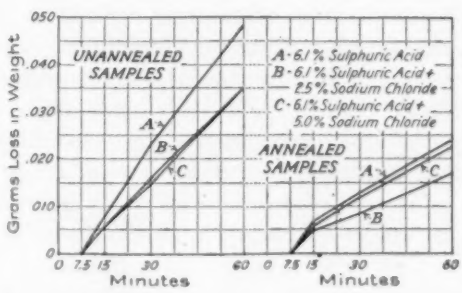

FIG. 13.—Shows retarding effect of addition of sodium chloride to sulphuric acid pickling bath.

IX. Conclusions

The results of this investigation show that a number of factors may influence the rate of pickling. Although these investigations necessarily had to be conducted along quantitative lines, the results and the following conclusions are stated along a qualitative or comparative basis, because other factors over which we have no control may also enter into the process.

(1) Increase of dissolved iron (ferrous sulphate) in a 6% sulphuric acid pickling bath at 130°F retards the rate of pickling.

(2) The data evidence no advantage in adding old pickle solution to a new sulphuric acid pickling bath.

(3) Increase of dissolved iron (ferrous chloride) in a 11.45% muriatic acid bath at 85°F increases the rate of pickling, although this is contrary to theory.

(4) Ferric sulphate in the sulphuric acid bath will accelerate the rate of pickling, but the difficulty of keeping this dissolved iron in the higher state of oxidation renders this fact of little commercial use.

(5) Decrease in acidity from 6.54 to 4.6% sulphuric acid lowers the rate of pickling, and vice versa, but

(6) Increase of pickling temperature accelerates the rate of pickling with sulphuric acid and will more than offset the weakening of acid in commercial use.

(7) Iron annealed at 1300°F for 1½ minutes loses from 250 to 400% more in weight during the early stages of pickling than unannealed iron, but there is less danger of "overpickling" the former.

(8) A monel metal basket in which the iron is placed in the pickling tank accelerates the rate of pickling.

(9) Addition of muriatic acid or sodium chloride to a sulphuric acid pickling bath, other conditions remaining constant, retards the rate of pickling.

THE ANNEALING OF GLASS—A NON-TECHNICAL PRESENTATION[1]

By A. N. Finn

Introduction

The rapid reduction in the temperature of glass which is incident to practically all commercial molding almost invariably produces a condition in the glass commonly known as "strain."[2] This condition must, in general, be removed before the ware is satisfactory for commercial purposes and its removal is called annealing or tempering.[3]

Strain is due to an inelastic yielding under the stresses developed within the body of the glass while cooling, because at any moment during this time the different parts of the body are not contracting at the same rate. During molding the surface of the hot glass coming in contact with the relatively cold mold shrinks or contracts very rapidly and is quickly cooled to a temperature at which the glass is rigid. The interior loses its heat more slowly and, consequently, contracts less rapidly than the surface which must, therefore, if the stresses become large enough, either crack or yield inelastically.

After the surface becomes rigid or at least practically so, it does not yield readily to any force applied to it and tends to resist the contraction of the hotter and relatively soft interior as it continues to cool and contract. This produces stresses in the glass, the surface usually being compressed while the interior is dilated. If these stresses exceed the strength of the glass, it will break. This may occur either during the initial cooling or subsequently whenever the glass is subjected to sudden temperature changes, such as those resulting from the action of hot or cold water. In order to reduce the liability of breakage of ordinary ware to a minimum, glass must be annealed.

The annealing of glass consists of two fundamental steps. The first is to heat it to such a temperature that the entire body of the glass becomes sufficiently soft to permit it to yield. Then, if sufficient time be allowed, the stresses developed during molding will disappear. The second is to cool it so slowly that the temperature differences between the interior of the glass and its surfaces, with the consequent differences in contraction, are not great enough to produce objectionable strain.

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[1] Published by permission of the Director, Bureau of Standards. Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga., Feb., 1926. (Glass Division.) Received March 29, 1926.

[2] This is permanent strain and should not be confused with temporary strain resulting from the application of external force or temperature differences.

[3] Tempering sometimes means the intentional introduction of strain, as, *e.g.*, in the heat treatment of glass to produce special physical properties.

The Annealing Range

In order to anneal glass most successfully, it is necessary to know the temperature range in which it can be done. At too high a temperature the glass will soften so much that it will lose its shape. If the temperature is too low, either an excessive amount of time will be required or the glass will not be annealed.

Several methods have been recommended for determining the annealing temperature for a glass. Among them the "cut and try" method, the bending rod method,[1] the method of observing the glass in polarized light during heating,[2] the location of the region of abnormal heat absorption,[3] and the measurement of the variation of the expansivity with temperature[4] may be mentioned.

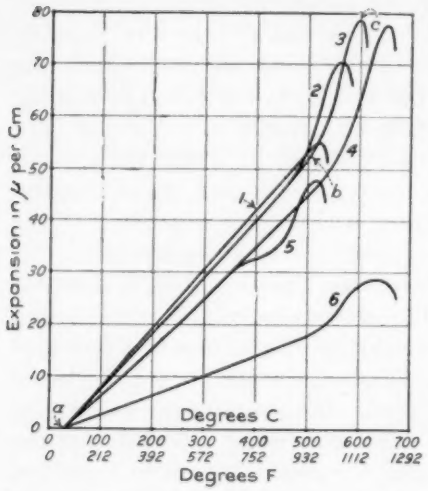

FIG. 1.—Thermal expansion curves of six glasses. See Table I for compositions.

Of these the last two seem, in general, to be most satisfactory. The heat absorption method not only locates the annealing range but also gives an idea as to how the particular sample was annealed. The thermal expansion method gives, in addition to the annealing range, definite information regarding the thermal expansion of the glass.

Figure 1 is taken from data obtained at the Bureau of Standards[4] and shows the thermal expansion curves of several commercial glasses whose approximate compositions are given in Table I.

It will be noted that all the curves are similar except No. 1. This similarity consists of a fairly straight line from *a* to *b* (indicating a uniform expansion in that temperature range), an abrupt change at *b* (indicating an increased rate of expansion) and a reversal of direction at *c* (indicating a material softening of the glass).

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[1] English and Turner, *Jour. Soc. Glass Tech.*, **2**, 90 (1918).

[2] Tool and Valasek, Bur. Stand., *Sci. Papzr*, No. 358 (1920); Adams and Williamson, *Jour. Frank. Inst.*, **190**, 597–631; 835–70 (1920).

[3] Tool and Eichlin, *Jour. Amer. Ceram. Soc.*, **8**, 1–17 (1925); *Jour. Op. Soc. of Am. and Rev. Sci. Inst.*, **8**, 419–49 (1924).

[4] Peters and Cragoe, Bur. Stand., *Sci. Paper*, No. 393 (1920).

TABLE I

APPROXIMATE PERCENTAGE COMPOSITION OF GLASSES NOS. 1–6

	SiO_2	CaO	MgO	Na_2O	Al_2O_3	B_2O_3
1	74	5	3	17	1	–
2*	74	6	3	17	–	–
3	72	11	–	17	–	–
4	72	15	1	12	–	–
5		Lead Tubing				
6	81	–	–	5	2	12

* Computed from batch composition.

The ordinary commercial annealing range of any of these glasses (except No. 1) is between the points *b* and *c*. However, since the "yield" or "flow" of the glass at *b* is very slow, it would take at least several hours to anneal it at this temperature. At *c* the "yield" is usually very rapid and the stresses or "strain" in the glass will be dissipated almost as soon as the glass reaches this point.

Curve 1 does not show an increase in the rate of expansion comparable with the section *bc* of the curves for the other glasses, since the available data show that the rate of expansion of this glass is practically uniform from room temperature to its softening point. From such a curve it is impossible to determine the whole range in which the glass could be annealed, but it does locate a very narrow range (about 512°C, 954°F) near an apparent softening point. The use of this narrow range would require very accurate temperature control in order to anneal the glass without danger of overheating it. Preliminary thermal absorption measurements on the same glass indicate that the annealing range is between 500°C and 530°C (932°F and 986°F), which gives greater latitude in controlling leer temperatures. Although it was reported that this glass could not be annealed satisfactorily, this was successfully accomplished in the first trial at the Bureau of Standards by holding it at 512°C (954°F) (as indicated by the curve) for 20 minutes before cooling slowly.

Figure 2 shows the heat absorption curves obtained from three portions of a piece of window glass.[1] These curves have two points in common, one at about 500°C (932°F) where heat absorption begins and one at about 610°C (1130°F) where this absorption ceases. The temperature range in which heat is absorbed is regarded as the annealing range and is comparable with the range *bc* of curve 3 in Fig. 1. The vertical displacement of the curves in Fig. 2 is associated with the degree of annealing of the respective samples, the upper curve being obtained with a highly strained sample and the lower one from a well annealed sample.

[1] Tool and Eichlin, *loc. cit.*

The Annealing Temperature and Time

Although stresses in glass are released very quickly at the maximum temperature of the annealing range, it does not follow that this temperature will be best suited for expeditious work.

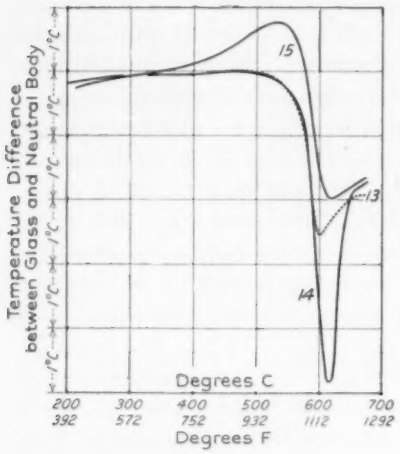


FIG. 2.—Heat absorption curves of a specimen of window glass. Curve No. 13, the original glass; No. 14 after annealing at 515°C; No. 15 after rapid cooling from 670°C.

Very thin ware can with safety be cooled rapidly from the maximum temperature, but the safe cooling rate decreases very rapidly as the thickness increases. Although the time required for annealing at lower temperatures is somewhat greater, it has been shown[1] that the use of lower annealing temperatures permits a more rapid cooling rate which more than compensates for the increased time for annealing.

The selection of the annealing temperature should then be governed by the thickness of the ware. An ordinary soda-lime glass which begins to soften at approximately 600°C (1110°F) can be annealed in about 30 minutes at 535°C (995°F), in two hours at 515°C (960°F), and in 10 hours at 490°C (914°F). These approximate the most satisfactory temperatures to use for ware whose thickness is 1, 2, or 5 cm.

The Cooling Rate

The cooling rate depends not only on the temperature from which the glass is cooled (the annealing temperature) but also on its thickness. Using the annealing temperatures mentioned above, the initial cooling rate for glass 1 cm. thick is about 100°C (180°F) per hour, for glass 2 cm. thick 25°C (45°F) per hour and for glass 5 cm. thick 4°C (7°F) per hour. But as the temperature falls, this rate can be increased, so that after the temperature has dropped about 35°C (63°F), it may become twice as great, *i.e.*, 200°C (360°F), 50°C (90°F), and 8°C (14°F) per hour and finally after a drop of 100°C (180°F), the rate per hour may be as high as 1500°C (2700°F), 400°C (720°F), and 60°C (108°F), respectively.

After this glass has been cooled below about 400°C (752°F), the rate may be increased still more without danger of introducing per-

[1] Adams and Williamson, *loc. cit.*

manent strain unless the temporary strain developed exceeds the strength of the glass and breaks it.

Temperature Control

The foregoing statements are based on the assumption that temperatures can be accurately controlled, a condition which is hard to obtain in many of the commercial leers in use. However, it is suggested that properly installed base-metal (chromel-alumel) thermocouples, connected with a suitable temperature indicator will help to improve and control the quality of annealing obtained in any plant.

Needless to say, the greater the uniformity in the temperature of any zone in the leer, both from side to side and from top to bottom, the better the grade of the annealing will be.

Apparatus for Detecting and Estimating Strain

Strain in glass is easily detected by means of polarized light, but since this is not a technical paper, any attempt to discuss polarized light would be out of place. However, a discussion of the fundamental principles of a strain detector, scleroscope, or polariscope is not out of place. Regardless of the names these instruments may have, they all involve the same principle.

A beam of light (white light) is either reflected from or passed through a "polarizer" which in the first case is usually a plate of black glass or, in the second, a number (pile) of thin transparent plates and in both cases the surfaces of these plates must make a definite angle with the beam. The reflected or transmitted beam then passes through the sample being tested and is again reflected at the same angle as before from another plate of black glass or is passed through a second pile of plates set at the proper angle. In either case these are called the "analyzer" and they are sometimes replaced by a nicol prism. From the character of the light finally passing the analyzer the degree of annealing is determined. If the sample is free from strain, no change in the intensity of the field (as compared with the field when no sample is used) or in the appearance of the sample will be observed; if it is moderately strained, the light will be brighter in certain areas; and if it is highly strained, it will appear colored, and the color will vary over the field of view.

If the analyzer is a nicol prism, a sensitive tint plate may be advantageously used because this, in a way, intensifies the effects obtained with moderately strained glass by producing a series of colors which can be more easily interpreted and compared with those obtained in testing other (standard) samples.

The apparatus used at the Bureau of Standards for determining the

"amount of strain" or the degree of annealing is so simple in construction and yet so eminently satisfactory that a detailed description of it will be given. (See Fig. 3.)

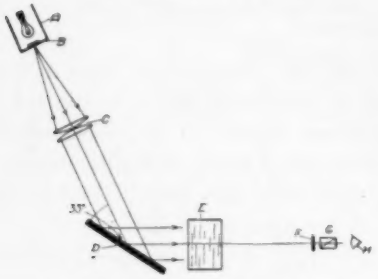


FIG. 3.—Sectional view of polariscope for testing glass for strain. *A*, source of illumination; *B*, ground glass; *C*, condensing lens; *D*, black glass plate (polarizer); *E*, sample to be tested; *F*, sensitive plate; *G*, nicol prism (analyzer); *H*, observer's eye.

Source of Light A 200-watt electric light bulb is enclosed in a box made of bright sheet metal. A ½-inch hole is cut in one side of the box and covered with a piece of glass whose surface is "fine" ground. This small piece of glass, illuminated by the lamp, is the actual source of light.

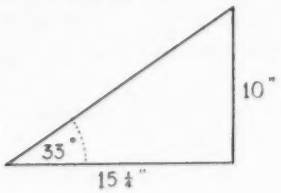
A condensing lens, 7 inches in diameter and having a 15-inch focal length, is so placed that its focus is at the "source of light." The light after passing through the lens is practically a parallel beam, but not entirely so since the source is not a "point."

Polarizer The beam of light then strikes a piece of polished black glass at an angle of approximately 33° (between the beam of light and the glass) or the angle which is necessary with the particular glass for obtaining the best polarization possible.[1] Although the beam of light reflected from the black glass is apparently not affected, it is, nevertheless, polarized.

Analyzer At some distance in front of the black glass polarizer a nicol prism is placed in the polarized beam, so that the enlarged image of the "source" is visible through it. By turning the nicol, the intensity of the light will change progressively from bright to dark. The nicol is properly set when the field is as dark as possible.

Tint Plate The tint plate, which should be a "First Order Purple" (retardation, about 575$\mu\mu$), is mounted directly in front of the nicol prism and is set by turning it until the color of the light passing through the prism is as marked as possible. Nicol prisms and

[1] An angle of 33° can easily be obtained as follows: Draw a right triangle with one side 15¼ inches and the other side 10.0 inches long. The angle between the long side and the hypotenuse will be about 33°. Thus:



tint plates can be obtained from practically any dealer in optical instruments.

If, now, a piece of strained glass is placed in the beam of light between the polarizing plate and the nicol, parts of the glass will apparently be colored differently than the original field. If well-annealed glass is examined, practically no change in color will be seen and if a highly strained piece of glass is used, the colors will be vivid. If the tint plate is removed and the same pieces of glass are examined, the first (moderate strain) will appear brighter in certain areas, the second (no strain) will produce no change, and the third (high strain) will be very bright or even colored in some places.

Irregular Shapes Some ware, on account of its irregular shape, can not be examined satisfactorily without putting it in a "tank." An immersion tank with two plate glass windows[1] (which should be free from strain) is satisfactory for this purpose and for best results it should contain a liquid whose index of refraction is as near as possible to that of the glass being tested.[2] Water or solutions of salts in water are better than nothing, but some organic liquids are much superior. Monochlor-benzene is very satisfactory for most soda-lime glasses; its odor is not disagreeable, but it is somewhat flammable and should not be used in too close proximity to fires. Carbon tetrachloride, although it does not have quite the right index of refraction, is much better than water and the fire risk is almost negligible.

Temperature Changes Glass being tested should be absolutely uniform in temperature. Ware taken from a room warmer or colder than the room in which the testing is done will show different amounts of strain than if allowed to come to thermal equilibrium. Even the effect of the heat from an inspector's hand will be pronounced, especially if the ware is thick. Ware directly from the leer may look very bad or very good, but after becoming cool it may look quite different.

Position of the Ware The exact position in which a piece of ware should be placed in the field of the polariscope is difficult to define, because it depends on the shape of the ware. However, this can be determined by examining the piece while gradually changing its position, the one desired being that in which the greatest change in intensity or coloration is observed.

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[1] Glass can be cemented to metal with a mixture of glue and plaster of Paris if the tank is to contain non-aqueous liquids, or with shellac and powdered flint if aqueous liquids are to be used.

[2] When the immersion liquid matches the glass, the immersed sample becomes practically invisible.

General Considerations

The question, "How well should glass be annealed" is frequently asked. There is no definite reply to this except to say that it should be sufficiently free from strain to serve the purpose for which it is intended. This can only be determined by experience, but with similar shapes in different sizes, the larger pieces should be more carefully annealed than the smaller ones.

The majority of ware should probably be very well annealed because practically all of it is subjected at times to sudden temperature changes. This is especially true of hollow ware, which is repeatedly washed with hot water or steam and then cooled rapidly. Plate and window glass might be stronger if it were not completely free from permanent strain because it would then be better able to withstand pressure, such as that produced by wind.

Standards The use of standard samples for controlling the effectiveness of the annealing operation is probably the most satisfactory method. Comparison of the daily work with such standards gives a definite idea of what is going on in the leer, and frequent comparison with properly selected standards will unquestionably assist glass manufacturers in determining and maintaining the conditions necessary to anneal their glass properly and consistently.

METHODS OF TESTING AND THE PHYSICAL PROPERTIES OF WET-PROCESS ELECTRICAL PORCELAIN[1]

By Louis Navias[2]

ABSTRACT

Data are given for the compressive, transverse, and tensile strengths of wet-process electrical porcelain.

Compressive Strength The height of the sample is an important variable. Initial failure and ultimate failure are discussed and it is suggested that as the latter is the more definite and constant of the two, the ultimate failure be always determined and recorded as the "compressive crushing strength." The cylindrical specimen 1 sq. in. in area (1⅛ in. diameter) and 1¼ in. high is recommended.

Transverse Strength The load applied to cause rupture is directly proportional to the cube of the diameter of the cylinder over a wide range of diameters. A cylinder with an area of 1 sq. in. is suggested. Cylindrical specimens give constant and high values.

Tensile Strength As the area of minimum cross-section increases the tensile strength decreases rapidly. The diameter should be given with determined values. An apparatus for making tensile strength determinations on a specimen with conically shaped ends and minimum area of 1 sq. in. is described.

Relationship of specimen size and effective dimensions to the average general dimensions of the ware and their methods of manufacture is discussed.

Introduction

In the last few years interest has been aroused in the subjects pertaining to the physical testing of porcelain to the extent that the American Society for Testing Materials included in its specifications some methods of testing issued under its designation D116–21T and reprinted in 1924 as D116–24T. These methods are tentative and subject to revision. Since then tests have been made and new methods of testing have been devised by interested groups. The purpose of this paper is to present the results of the work in order to create further interest and to give some definite information upon which discussion and future work may be based. Parenthetically it may also be stated that the literature of the American Ceramic Society is lacking not only in such data but also in the critical survey of the tests themselves which makes for better comprehension of the numerical results obtained from the tests.

The statement cannot be over-emphasized that the physical properties of a material like porcelain made by the wet-process method are dependent upon the batch composition, the methods of working in the green state, and upon the firing, and that changes in these processes are reflected in the physical properties. Of the possible defects the

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[1] Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga., Feb., 1926. (White Wares Division.)

[2] Research Laboratory, General Electrical Co., Schenectady, N. Y.

working in the green state is especially interesting in the study of testing, for the final shape and constitution of the porcelain test specimen are dependent on the methods involved and on the precautions taken.

Tamping by hand in a rectangular mold has long been a common practice. There is no need here to dwell on the subject of flaws, as air pockets, surfaces of contact between two separately tamped layers, rough edges, and the like, that are prevalent. Test specimens have also been obtained from a column extruded through a die with such machines as pug mills, screw, and hydraulic presses. Each type of ware is usually manufactured from a blank of plastic material obtained by one of these processes, and it appears reasonable to suggest that the test specimens should be made under similar conditions where possible. Laminations and segregations will always have to be guarded against, not only in the commercial practice but also in the experimental and testing practice.

For a number of reasons the writer has felt that a cylindrical specimen is better adapted for most physical tests than a specimen with a square, rectangular, or "rounded corner" square cross-section. Circular dies are most used in the manufacture of electrical porcelain. Sections of the cylindrical column after drying can be further worked or formed into test specimens and trued to shape and dimensions by turning in a lathe, the specimen being held either by one or both ends and worked down by metal tools or abrasive wheels. The perfection of manipulation in the production of test specimens is always desirable.

The dimensions of the test specimen are important from two considerations. In the first place, where possible, the test specimen should compare with the general type of merchandise under consideration in at least one dimension, which will usually be the thickness. Dishware, spark plugs, and bushings may be made from the same porcelain, and the test specimens representative of these widely different articles should show corresponding effective dimensions. From a second consideration there should be some proximity and correlation between effective dimensions of specimens used in different tests. Calculations are usually made and expressed in units as lbs. per sq. in. or kg. per sq. cm., quite often necessitating the use of large factors to obtain the common units. For any one particular property quite often no relationship has been found between changes in dimensions and the corresponding changes in the property under investigation. By association, such data of different properties as for instance tensile and compressive strengths may be correlated and false conclusions drawn. Until more information is obtained for the correlating of these values, the practice

of stating the exact dimensions of the test specimens together with the calculated unit values is very commendable.

In the present case a cylinder whose area is 1 sq. in. (diameter $1\frac{1}{8}$ in.) has been taken to fulfill the conditions enumerated above. Where the height of the cylinder is involved as a variable in the calculation or where the height plays an important part although not specifically included in the formula (as for instance in compressive strength) it has been felt desirable to maintain it near the value of 1 to $1\frac{1}{8}$ in. It is anticipated that other properties and the methods of obtaining them will be forthcoming as time permits.

Compressive Strength

The A.S.T.M. specifications D116–21T call for a specimen cylinder $1\frac{1}{2}$ in. in diameter and 1 in. high with ground plane parallel surfaces. In test, the specimen is to be placed between contact pads of blotting paper $\frac{1}{32}$ in. thick. For this test the writer has advocated a specimen $1\frac{1}{8}$ in. diameter and $1\frac{1}{8}$ in. high, the height being equivalent to the diameter. Others have advocated that the height should be at least twice the diameter, Riddle and Laird[1] using a specimen 1 in. diameter and $2\frac{1}{2}$ in. high.

Effect of Height of Specimen on Compressive Strength

The height of the specimen does not enter into the calculation for determining the compressive strength per unit area but nevertheless it plays an important part in the magnitude of the result. Table I gives a number of examples. The specimens were cut from cylinders of plastic material squirted through a die in a hydraulic press. When dry the opposite faces were rubbed down nearly parallel, and after forming they were ground parallel. In experiment No. 130 doubling the height decreases the average crushing strength from 58,100 to 42,800 lbs. per sq. in., a lowering of 26%. In experiment No. 318 increasing the height by one-half lowers the average crushing strength from 75,700 to 58,100 lbs. per sq. in., a lowering of 23%, whereas doubling the height decreases the crushing strength from 75,700 to 49,400 lbs. per sq. in., a decrease of 35%. The height is an important function of the values obtained for compressive (crushing) strength.

Initial and Ultimate Failure

Porcelain is a brittle material and its behavior under compression is unlike materials which flow under stress. As the load is applied to the porcelain specimen two failures are generally noticeable. The initial failure manifests itself by some disturbance around the specimen, as for

[1] F. H. Riddle and J. S. Laird, "The Tensile Strength of Porcelain," *Jour. Amer. Ceram. Soc.*, **5**, 385 (1922).

instance, caused by the spalling of chips of porcelain. At other times no disintegration is visible although there has been a very decided tremor which would indicate that there has been a readjustment in the parts of the machine. These readjustments may sometimes be due to unequal speed of application of the working load. In most cases, however, initial failure is accompanied by a fracture of the specimen parallel to its height and parallel to the direction of the application of the load, the specimen usually being severed into two halves. This observation has also been recorded by Riddle and Laird[1] who state, "Failure under test with the specimens was a little peculiar as in most cases there first occurred a splitting of the specimens into longitudinal segments." In all cases the specimens remained in position in the machine, and considerable load had to be applied before the ultimate compressive (crushing) strength was attained. In some instances there was no aural evidence of initial failure and the only values obtained were ultimate crushing strengths.

The recognition of the initial failure is greatly dependent upon the alertness of the operator of the testing machine, whereas the ultimate failure is unmistakable for the specimen is literally crushed into numerous small fragments with great force, and the event takes place in a very short period of time. It is a dangerous practice to view the specimen during the process of compression, for particles may be thrown off with high velocity at any time.

In Table I values are given for the loads at initial and ultimate ailure. From the ultimate load and the dimensions of the specimen the compressive (crushing) strength is calculated. The numbers in parentheses in the column "Initial Failure" refer to the number of specimens for which values of initial failure were obtained. The difference between this number and the total number of specimens in each group gives the number of specimens for which no initial failure was observed. No numerical relationship can be found to exist between the loads applied at initial and ultimate failures, although it would be expected that as the height of the specimen was increased the divergence between initial and ultimate loads would decrease. In experiment No. 130 doubling the height made great differences in the actual values of initial and ultimate load, but no difference in the ratio between them, the initial failure occurring at a value 47% of that of the ultimate failure. In experiment No. 318, the ratios are respectively 49, 54, and 71% as the height is increased. On account of the uncertainties connected with the determination of the initial failure the writer feels

[1] *Jour. Amer. Ceram. Soc.*, **5**, 59–61 (1922) Part II.

TABLE I

COMPRESSIVE STRENGTH

EXPERIMENT NO. 130 FIRED TO CONE 10

Specimen no.	Av. height	Av. diameter	Initial failure load in lbs.	Ultimate failure load in lbs.	Compressive crushing strength lbs. per sq. in.
6	0.760″	1.467″	(4) 46,500	98,300	58,100
Maximum					72,000
Minimum					49,300
Average deviation from the mean	1.05%	0.61%			9.3%
6	1.508″	1.479″	(6) 34,700	73,400	42,800
Maximum					47,000
Minimum					36,500
Average deviation	1.00%	0.41%			8.2%
		EXPERIMENT NO. 318 FIRED TO CONE 10½			
10	2.277″	1.091″	(9) 32,900	46,100	49,400
Maximum			44,000	62,000	66,900
Minimum			26,000	34,000	36,700
Average deviation	0.4%	0.5%	14.7%	12.8%	12.2%
10	1.714″	1.092″	(9) 29,200	54,400	58,100
Maximum			40,500	62,500	66,500
Minimum			24,000	42,000	44,700
Average deviation	0.5%	0.4%	13.0%	7.2%	7.1%
10	1.139″	1.096″	(7) 35,000	71,300	75,700
Maximum			45,000	80,500	84,300
Minimum			26,000	57,500	61,900
Average deviation	0.6%	0.5%	18.9%	9.4%	9.1%
		EXPERIMENT NO. 178 FIRED TO CONE 9 (UNDERFIRED)			
6	1.44″	1.072″	(6) 32,500	52,100	57,900
Maximum					67,000
Minimum					51,000
Average deviation	0.7%	0.9%			10.6%
6	1.139″	1.081″	(6) 30,900	53,200	58,000
Maximum					72,000
Minimum					48,600
Average deviation	1.3%	0.6%			12.6%

that its determination should be merely an incidental observation in the determination of the ultimate compressive (crushing) strength. There would be greater clarity of purpose and no confusion with regard to the failure concerned in the test, if the test were named "compressive crushing strength," or by some phrase including the word "crushing."

Experiment No. 178 indicates the effect of underfiring on the compressive strength. The results should be compared with those of Experiment No. 318 for the same sized specimen.

Transverse Strength (Modulus of Rupture)

In the *1921–22 Yearbook*[1] *of the American Ceramic Society* a tentative method for transverse strength requires a "green" specimen in the shape of a bar 7 in. long and 1 in. square cross-section, to be broken on knife edges 5 in. apart. No reference is made to the testing of fired specimens. The A.S.T.M. makes no mention in its tentative or approved specifications of a transverse strength test for porcelain.

Cylindrical Specimen The following tests were made on cylinders of fired wet-process electrical porcelain. The cylinders are 6 in. long and were broken while supported on a span of 5 in. The block supports and the inverted wedge to which the load was applied, were made of triangular shaped steel blocks, the contact angle 45°, and the edges rounded to 0.125 in. radius. The modulus of rupture is calculated from the formula:

$$M = \frac{8\,PL}{\pi d^3}$$

where M = modulus of rupture
P = load in lbs. at rupture
L = distance between supports in inches
π = 3.1416
d = diameter of specimen in inches

In Table II are given data of the modulus of rupture on a number of specimens. One series, experiment No. 130, was made to determine the effect of changes in diameter. Throughout a wide range of diameters the modulus remains the same, indicating that the load at rupture is directly proportional to the cube of the diameter. The maximum variation in diameter of the cylinders was roughly threefold, with a corresponding variation in area of sevenfold and variation in d^3 of twentyfold.

Comment on the test has been made to the effect that a round specimen gives only point contacts for support and that such a condition may cause a decrease in the apparent strength. Sufficient data have been presented to show that the values are quite consistent. Felix Singer[2] gives for the highest value of the modulus of rupture of a number of porcelains, 855 kg. per sq. cm. equivalent to 12,200 lbs. per sq. in., the average value being much lower. Rosen-

[1] *Jour. Amer. Ceram. Soc.*, **5**, 59–61 (1922). Pt. II.

[2] Felix Singer "Die Keramik in Dienste von Industrie und Volkswirtschaft," p. 472 (1923).

thal[1] gives the maximum value of 590 kg. per sq. cm. for electrical porcelain, corresponding to 8,400 lbs. per sq. in. These facts are included to show that the data obtained with a cylindrical specimen give not only consistent but high values as well. A specimen with flat surfaces is subject to the requirement that the faces in contact with the wedges must be not only truly plane but also parallel in order to present line contacts and to prevent shear. Warping during firing is a much more serious condition with a flat-faced specimen than with a cylinder.

TABLE II

TRANSVERSE STRENGTH

Specimens	Diameter in in.	Av. deviation	d^3	Load in. lbs.	Modulus of rupture Lbs. per sq. in.	Av. dev.
EXPERIMENT NO. 130 FIRED TO CONE 10						
6	0.489	0.82%	.117	95	10,300	3.4%
6	0.749	0.27	.420	281	8,500	5.6
6	1.011	0.30	1.027	850	10,500	1.9
6	1.121	0.54	1.403	1120	10,200	4.4
6	1.113	0.27	1.371	1104	10,200	4.7
5	1.335	1.4	2.362	1855	10,000	4.2
6	1.345	0.45	2.422	1938	10,200	5.9
EXPERIMENT NO. 198 FIRED TO CONE 8½						
6	1.103	0.46%			12,100	5.7%
EXPERIMENT NO. 198 FIRED TO CONE 11¼						
6	1.106	0.54%			11,000	5.3%
EXPERIMENT NO. 197 FIRED TO CONE 10						
6	1.102	0.27%			11,500	2.6%

Tensile Strength of Porcelain

Riddle and Laird[2] have described in detail a method for the determination of the tensile strength of porcelain, with specimens whose area at the minimum cross-section was 0.135 sq. in. (a diameter of 0.4 in.). This method has been included in the tentative specifications of the A.S.T.M., D116–21T. It is readily acknowledged that the test is applicable to the size of specimens advocated, but it is a question whether the tensile strength expressed as so many lbs. per sq. in., obtained from testing a specimen whose area is only 0.135 sq. in., can be considered as the tensile strength of the same material when the

[1] In Searle's, The Chemistry and Physics of Clays and Other Ceramic Materials, p. 178 (1924).

[2] F. H. Riddle and J. S. Laird "The Tensile Strength of Porcelain." *Jour. Amer. Ceram. Soc.*, **5**, 385–93 (1922).

determination is made on a specimen whose minimum cross-section area is actually 1 sq. in. Riddle and Laird have given the answer to this question in the same paper, where they have plotted the tensile strengths of porcelain specimens against the area and diameter. The results for the larger specimens given below were determined from their graphs, as the actual values are not given.

TENSILE STRENGTH IN LBS. PER SQ. IN.

Diameter (in.)	Special porcelain	Triaxial porcelain
0.4	9,500	5,800
1.125	7,300	*4,600
2.25	4,300	2,800

* Found by interpolation.

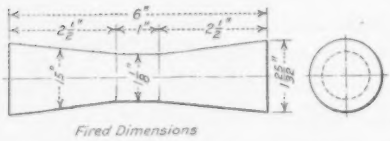

FIG. 1.—Test specimen for determining tensile strength of porcelain.

Although the area of minimum cross-section enters into the calculation of the tensile strength, the tensile strengths decrease rapidly as the area is increased. It seems therefore necessary to require that test specimens have such critical dimensions which will make them comparable with and representative of thicknesses of the material as used in practice. For spark plug porcelains a small specimen similar in dimensions is desirable and for much heavier articles as bushings of electrical porcelain a larger specimen is required. If such differences are recognized there should be no difficulty in interpreting the facts when the practice is followed of giving the diameter of the specimen as well as the calculated tensile strength.

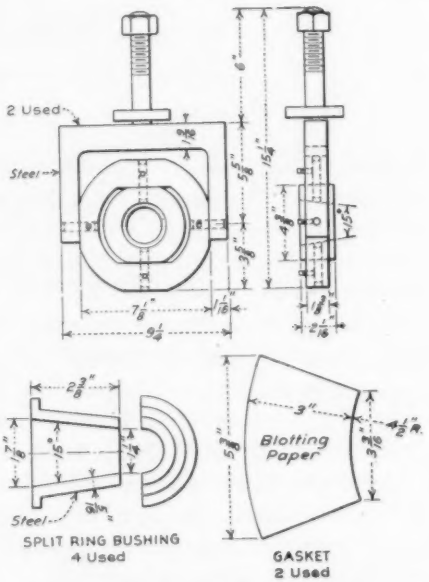

FIG. 2.—Grips used in determining tensile strength of porcelain.

New Apparatus for Tensile Strength

In the present instance an apparatus has been developed for determining the tensile strength of a porcelain specimen whose minimum section has an area of 1 sq. in. Fig. 1 represents the specimen. Specimens 5

inches long instead of 6 inches may be used as effectively. Of main importance is the correct angular and conical tapering to give a good fit in the grips of the apparatus. The specimens are usually turned from a cylinder on a lathe using a cutting metal tool or an abrasive wheel. Figure 2 gives the details of construction of the parts of the apparatus, while Figs. 3 and 4 show views of the apparatus in the test machine.

A suitable grip for holding the specimen in the tensile machine is shown, in which two grips are used. The split ring bushing fits into a conical retaining ring, which swings on two pins within an outer retaining ring, the latter being pivoted on pins in a yoke. The two retaining rings are thus pivoted at right angles to each other. The two yokes may also be placed at right angles to each other.

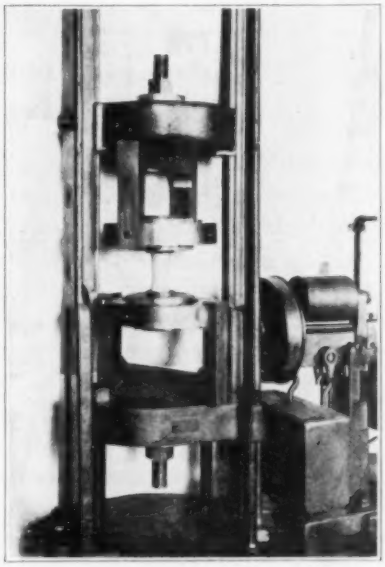

FIG. 3.—Grips and test specimen assembled in testing machine for determining tensile strength of porcelain.

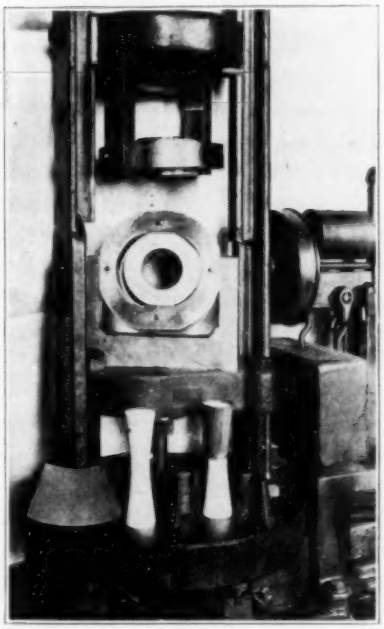

FIG. 4.—Disassembled view of grips and test specimen for determining tensile strength of porcelain.

Blotting paper gaskets $\frac{1}{64}$ in. thick, or sheet lead gaskets $\frac{1}{32}$ in. thick have been used. The blotting paper gaskets are cut to fit and are temporarily held in place during the assembling by a simple wire clamp. During the tension the blotting paper of a number of trials was found to have been compressed from 18 mils to 14.2 mils, namely by $\frac{1}{5}$ of the thickness.

Results on a set of samples are given in Table III. The results are particularly uniform and give not only a high value for the tensile strength but also a small percentage average deviation from the mean.

TABLE III

TENSILE STRENGTH

EXPERIMENT NO. 130 FIRED TO CONE 10

Specimen no.	Diameter at break (in.)	Cross-section (area)	Tensile strength lbs. per sq. in.
1	1.120	0.985	7130
2	1.047	0.860	6540
3	1.048	0.862	7030
4	1.061	0.882	7090
5	1.090	0.932	7280
6	1.075	0.909	7060
		Average	7020
		Average deviation from the mean	2.3%

EXPERIMENT NO. 329 FIRED TO CONE 9½ IN MUFFLE KILN

1	1.084	0.923	6030
2	1.068	0.895	6940
3	1.090	0.934	7100
4	1.075	0.907	5660
5	1.084	0.924	5940
6	1.083	0.921	6040
		Average	6290
		Average deviation from the mean	7.8%

Sets of specimens not fired as well as these give lower values with greater deviations, as illustrated in Experiment No. 329. In this case lead gaskets $\frac{1}{32}$ in. thick were used.

Conclusions

Compressive Strength

(1) The height of the porcelain specimen is an important function and should be noted, although it does not appear in the calculation.

(2) The initial failure cannot be considered a critical property of the porcelain as its determination is greatly dependent upon the working of the testing machine and the alertness of theoperator.

(3) The ultimate failure is a definite unmistakable event. To eliminate confusion with the determination of initial failure, the ultimate failure should be designated as the "compressive crushing strength."

(4) There is no advantage in increasing (or decreasing) the height of the specimen above (or below) the 1 to 1 ratio of height to diameter.

Transverse Strength

(1) Over a wide range of diameters the load applied to cylindrical specimens of porcelain to cause rupture is directly proportional to the cube of the diameter of the cylinder, yielding a definite value for the modulus of rupture.

(2) With a cylinder supported on straight-edged wedges, consistent and high values for the modulus of rupture are obtained.

Tensile Strength

(1) The tensile strength increases as the cross-section of the specimen decreases, but no mathematical relationship has been found to exist between them. For this reason values of tensile strength given in conventional units should be accompanied by the dimensions of the specimen.

(2) An apparatus for making tensile strength determinations on a specimen, with conically shaped ends, of minimum area 1 sq. in. is described.

In general it has been found that for electrical porcelain effective dimensions of 1 inch (and areas of 1 sq. in.) for test specimens in compressive, transverse, and tensile strength tests are suitable. The actual dimensions and the methods of testing are given.

The writer wishes to acknowledge the aid given in the testing of the specimens by Frank L. Michael of this Laboratory and by the members of the staff of the General Engineering Laboratory.

SOME PROPERTIES OF FUSED QUARTZ AND OTHER FORMS OF SILICON-DIOXIDE[1]

By H. L. Watson[2]

ABSTRACT

A compilation of data on the physical properties of silicon-dioxide.

Introduction

The purpose of this paper is to set forth under one heading, the data on quartz in its various forms scattered throughout the technical press where it can be obtained only at the expense of considerable time and often of considerable effort.

The data was selected with a view toward covering the various characteristics, and no pretense is made as to a complete bibliography of data available. Neither is it the purpose to discuss the very excellent development of processes and manufacture of fused quartz products resulting from the work of E. Thomson, E. R. Berry, P. K. Devers, L. B. Miller, S. Boyer, B. F. Nieder, I. F. Hooper, E. Herzog, D. P. Gallant, and H. L. Watson, of the Thomson Research Laboratory, of the General Electric Co. at Lynn, Massachusetts, which work constitutes the subject matter of several papers before prominent technical societies.

The oxide of silicon (SiO_2) is found in many allotropic forms. Silica is one of the constituents of granite, gneiss, and other crystalline rocks. It forms quartzite and sandstone, and composes the mass of sand at the seashore. As quartz, it occurs crystallized and massive, and in both states is widely distributed. When crystallized it commonly exists in hexagonal prisms, terminated by hexagonal pyramids. It belongs to the rhombohedral division of the hexagonal system and its forms are sometimes very complex. Silica occurs in cryptocrystalline and amorphous forms which are anhydrous or physically hydrated. The crystalline forms are generally anhydrous, as quartz, tridymite, and cristobalite, although lussatite (a fibrous variety of tridymite) contains 7% of water.

"The average composition of the lithosphere is very nearly that of the igneous rocks alone."[3] Since average igneous rock contains approximately 60% silicon-dioxide it follows that the earth's crust contains nearly the same percentage of this material. Clarke gives 59.77 as

[1] Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga., Feb. 1926. (Glass Division.)

[2] It is desired to acknowledge the service of J. W. Johnson of this Laboratory in compiling these data.

Thomson Research Laboratory, General Electric Co., Lynn, Mass.

[3] F. W. Clarke, The Data of Geochemistry.

the most probable value for the percentage of silicon-dioxide in the lithosphere. The percentage of SiO_2 in the mass of the earth, of course, is not known and cannot be estimated.

An amorphous anhydrous product is obtained by the fusion of any of the natural forms of silica. Natural fused quartz is found in several igneous rocks.

Silica fused by lightning has been found in many countries, particularly in the form of long tubes, $\frac{1}{4}$ to $\frac{1}{2}$ in. in diameter, produced by the passage of the electric discharge through a bed of silica sand. These are known as fulgurites or Le Chatelierite, and were first observed in 1711 by Herman in Silesia, and attributed to lightning by Dr. Hentzen, in Westphalia, in 1805. Darwin in the "Voyage of H. M. S. Beagle" refers to the Uruguayan fulgurites.[1]

The various forms of silica can be catalogued with reference to their physical structure. The allotropic varieties of crystalline silica are as follows: crystallized silica in the form of quartz, tridymite, and cristobalite.

Each of these crystalline varieties of silica has at least two forms. The different forms have different physical and even chemical properties. Under certain conditions and at definite temperatures, transformations of state may take place. The transformations are reversible.

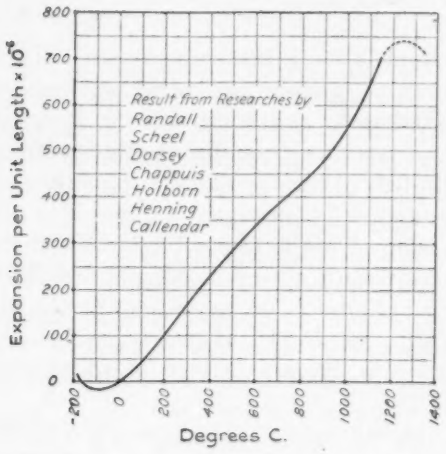

FIG. 1.—Thermal expansion of fused silica.

Quartz

At atmospheric temperatures crystal quartz can exist only in the α state. As already stated, it occurs in abundance. The luster is vitreous, or in some cases, greasy to dull. Colors of quartz specimens are various, as white or milk white, (milk quartz); purple or bluish violet (amethyst); smoky yellow or brown (smoky quartz) or Cairngorm stone, called morion when black or nearly so; yellow false topaz or citrine; aventurine, spangled with scales of mica or hematite; sagenite, containing acicular crystals of rutile; the cat's-eye, opalescent through the presence of asbestos fibers; and others.[2]

[1] Richard Paget, Fused Silica.

[2] Century Dictionary.

The cause of the color in rose quartz has been investigated by E. F. Holden.[1] The evidence obtained favors the conclusion that this variety of quartz is colored by the presence of trivalent manganese. The color of rose quartz can be closely imitated by dissolving less than 0.01% of manganese in a silica gel. In this case as in actual rose quartz, the color disappears on heating to the transition temperature of 575°C. The same author has shown that the color of citrine, like that of colloidal solutions of ferric hydrate, is due to submicroscopic particles of hydrous ferric oxide.

"The effect of radium radiations on white or rose quartz is invariably to produce a dark smoky color, and it is interesting to notice that smoky quartz is a constant associate of radioactive minerals in Madagascar and Ontario, whereas rose quartz is not."[2]

Colorless crystal quartz is generally known as rock crystal. As stated, it commonly occurs in hexagonal prisms terminated by hexagonal pyramids. Some of the corners are, however, modified by small faces of other type. In crystallography, α quartz is placed in the trapezohedral class of the trigonal system, possessing three-fold symmetry about a vertical axis. Optically it is remarkable as exhibiting the phenomenon of circular polarization, the right and left hand character of the crystals optically corresponding to the arrangement of trapezohedral planes present.[3]

The symmetry of quartz crystals is, in fact, only ternary, and not hexagonal. One rhombohedron, generally better developed than the other, is said to belong to the direct form (with corrosion striae perpendicular to the axis) and the other to the inverse form. The two forms of rhombohedron are distinguished as right and left, according to the direction in which they cause rotation of the plane of polarized light.[4]

Crystal quartz is highly transparent to ultra-violet radiation. It scratches glass

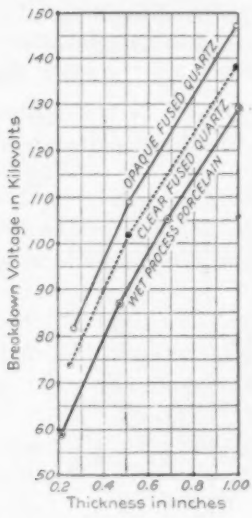

FIG. 2.—Dielectric strength of quartz and porcelain. Tests made under oil at 25°–60 cycles–1 in. spherical electrodes. Voltage raised 1 kv. per second from 0.

[1] E. F. Holden, *Amer. Mineralogist*, **8**, April, 1924.

[2] *Nature*, Nov. 8, 1924.

[3] M. L. Huggins, "The Crystal Structure of Quartz," *Phys. Rev.*

[4] J. A. Audley, Silica and the Silicates.

readily (hardness 5–7) and becomes electrified by friction and also by heating and pressure. (Quartz is piezo-and pyro-electrically active). It is highly resistant to corrosion by various acids and alkalis and is insoluble except in hydrofluoric acid, hot concentrated phosphoric acid, and hot alkalis. Some of the more important physical constants are shown in the following:

SOME PHYSICAL CONSTANTS OF α QUARTZ

Specific gravity*	2.646
Sp. volume cc./g.*	.3779
Thermal conductivity in gram calories*	
Parallel to axis	.0325
Perpendicular to axis	.0586
Linear expansion*	
Parallel to axis (t, 0–80°) C x 10^4 = .1337 or	.00001337
Perpendicular to axis (t, 0–80°) C x 10^4 = .0797	.00000797
Cubical expansion (t, 0–100) C x 10^4 = .3840	.00003840
Specific heat (t, 12–100) g. calories	.188
Index of refraction*	
Wave length .395μ	1.55815
Wave length .760μ	1.53917

Transmissibility to Radiation

Quartz is transparent to ultra-violet. Pfluger gives transmission values for a plate 1 cm. thick as follows:

.222μ	94.2%*
.214	92.0
.203	83.6
.186	67.2

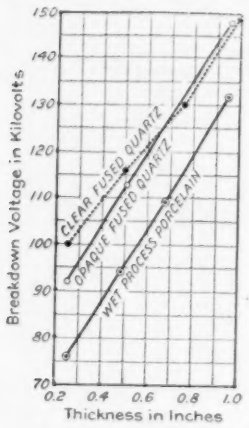

FIG. 3.—Dielectric strength of quartz and porcelain. Tests made under oil at 50°C–60 cycles–1 in. spherical electrodes. Voltage raised 1 kv. per second from 0.

C. P. Goertz states that crystal quartz has the same transmission as fused quartz for radiation in the region between 450 and 300 millionths mm. (4500 to 3000 Å). George Joos reports[1] as the result of some experiments on the transmission of the copper spectrum through clear and crystal quartz plates of 6 mm. thickness, that absorption only starts under 2000 Å and is moderate even at 1980 Å.

Crystal quartz transmits radiation in the visible region of the spectrum almost perfectly.

The transmission of infra-red radiation of very long wave length is not the same in crystal quartz as in the clear fused variety.

* Smithsonian Institution.

[1] G. Joos, *Phys. Zeit.*, **25** [15], 374–76 (1924).

Crystal quartz is opaque to radiation of 7μ, (70000 Å or .007 mm.) at 8.50μ metallic reflection occurs. At wave length 24.4μ it is again transparent. At wave length 108μ crystal quartz is transparent whereas the clear fused variety is completely opaque.[1]

The specific inductive capacity is not the same in all directions in a crystal. It depends upon the direction of the plane to the optic axis. For wave lengths greater than 10,000 cm. the specific inductive capacity,[1] parallel to axis = 4.69 and[1] perpendicular to axis = 5.06.

Transformation of Crystal Quartz

The alpha quartz discussed in the preceding is apparently stable at temperatures below 575°C. When brought to this temperature it changes its physical properties, entering the β state. The constants for the β state have not been determined; however, the transformation is marked by a sudden volumetric change which breaks the crystal into a great number of pieces.

The transformation is reversible and very sensitive. A variation of 0.1°C is sufficient to determine the change from α to β. The reverse transformation of β to α does not occur at 575°C but 5° lower at 570°C. The density of β quartz is thought to be 2.633.[2]

Tridymite

Tridymite is a crystallized variety of silica found in minute transparent tabular hexagonal crystals in tachyte and other igneous rocks, usually in twinned groups, and commonly of three crystals. It also occurs in plates of hexagonal shape consisting of agglomerations of biaxial orthorhombic crystals.

It is thought that there are three forms of tridymite. The α tridymite changes to β_1 tridymite at 117°C, the temperature of transformation. At 163°C, β_1 tridymite changes to β_2 tridymite. The transformations are reversible.

Tridymite is soluble in hydrochloric acid and in boiling sodium carbonate.[3] Some of its physical constants follow:[2]

Specific gravity α form	2.28
Index of refraction (D_1) 0.469 to	1.473
Melting point	1670°C

Tridymite is easily produced by heating crystal quartz sand in the presence of "mineralizing" agents (as chloride of potassium or lithium) at between 800° and 1500°C. It is also produced (with cristobalite) in the absence of "mineralizing" agents when crystal quartz sand is

[1] Smithsonian Institution.
[2] G. Flusin, "Le Verre de Silice," *Chem. et Industrie.*
[3] Century Dictionary.

heated in the electric furnace for a short time at near the point of fusion (about 1700°C).[1]

Fused quartz heated in the presence of a suitable catalyst such as chloride of potassium or lithium, devitrifies at comparatively low temperatures; thus, continuous heating for eight days at 800°C converts vitreous silica into tridymite.[2]

Cristobalite

This variety of silica has at least two forms, called α and β. The α cristobalite is found in small octohedric crystals. The β cristobalite crystals are cubical. The transition point is variable.[3]

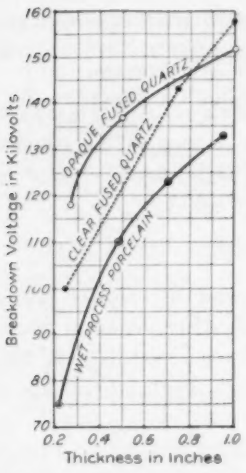

FIG. 4.—Dielectric strength of quartz and porcelain. Tests made under oil at 100°C–60 cycles–1 in. spherical electrodes. Voltage raised 1 kv. per second from 0.

If the cristobalite has been formed at 1600°C the transition point is 270°C on heating, and 230°C on cooling. It diminishes to as low as 220° and 200°C and depends upon the magnitude of the previous highest heating temperature.[4]

Cristobalite is formed by heating precipitated silica at 1000°C. Both crystal quartz and fused quartz are transformed to cristobalite by heating at 1000°C. The speed of reaction is a function of the temperature, grain size, time of heating, and purity of the silica.

"Devitrification scarcely commences at 1120°C but is appreciable after four hours of continuous heating at 1140°C."[2]

The specific gravity of cristobalite[4]	=2.32
The melting point is about	1700°C
Ferguson and Merwin[5]	1710°C
Rudolph Wietzel[4]	1696°C
Index of refraction[5] (D_1) 1.484 to	1.487

Transformation of Crystalline Silica

The three crystalline varieties of silica can be transformed from one form to another by heating at 870°C.[6] The speed of reaction is very slow but increases with increase of temperature. The mechanism determining these transformations is imperfectly understood.

[1] Thomson Research Lab., G. E. Co., H. L. Watson.

[2] Richard Paget, *loc. cit.*

[3] Fenner, *Z. Anorg. Chem.*, **85**, 133 (1914).

[4] R. Wietzel, The Equilibrium Relations of Fused and Crystal Phases of SiO_2.

[5] Ferguson and Merwin, *Amer. Jour. Sci.*, **45**, 322 (1918).

[6] G. Flusin, *loc. cit.*

Cryptocrystalline Forms of Silica

The cryptocrystalline forms of silica are generally physically hydrated. Specimens consist of agglomerations of microscopic particles of anhydrous silica separated by ultramicroscopic spaces (diameter of the order of 1.1×10^{-5} mm.) filled with water.[1]

The cryptocrystalline varieties are named according to color or structure. The following belong in this class:[2]

chalcedony	agatized wood	hornstone
onyx	agate (in many forms)	jasper
sardonyx	prase	basanite
carnelian	chrysoprase	
heliotrope	flint	

Natural Hydrated Amorphous Forms

Opal and tripoli do not show, even under the microscope, evidence of crystallization and are generally considered amorphous. Various forms of opal have specific gravity of 1.9 and 2.3, and contain from 3 to 9% of water. There are many varieties as: (*a*) precious or noble opal (including the harlequin opal) with brilliant and changeable reflections of green, yellow, and red; (*b*) the fire opal, which affords an internal red fire-like reflection; (*c*) common opal, whose colors are white, green, yellow, and red but without the play of colors; (*d*) semiopal, the varieties of which are more opaque than common opal; (*e*) hydrophane, which is transparent only when immersed in water; (*f*) hyalite, which occurs in small globular and botryoidal forms, colorless and transparent with vitreous luster; (*g*) menilite, which occurs in irregular or reniform masses and is opaque or translucent; (*h*) and fiorite, siliceous sinter, or geyserite, the form of silica deposited by hot springs and geysers.

The production of artificial hydrated forms of silica of the opal type seems not to have attracted the attention of experimenters.

Tripoli or tripolite, the second hydrated amorphous type of silica, called infusorial earth, is formed of the siliceous shells of diatoms.

Artificial Hydrated Amorphous Silica

Chemically precipitated silica (SiO_2) is the only amorphous hydrated type that has been so far produced. When first precipitated it contains 90% of water. This can be reduced to about 3% by drying.

Precipitated silica changes gradually to cristobalite when heated at 1000°C.

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[1] G. Flusin, *loc. cit.*

[2] Century Dictionary

Fused Quartz
Amorphous Anhydrous Silica

All crystalline forms of silica are transformed at sufficiently high temperatures into an amorphous anhydrous product, which may be clear, opaque, or translucent, and which has important physical properties.

The fusion of clear quartz intended for optical purposes requires the careful selection of crystals free from inclusions. Quartz crystals may contain microscopic drops of water, carbonic acid, sodium chloride, and small particles of glass. Crystals of different origin produce different results in fusion. Helberger states as the result of tests made on crystals from various sources, that material obtained from Gotthard and Brazil was found most suitable.[1]

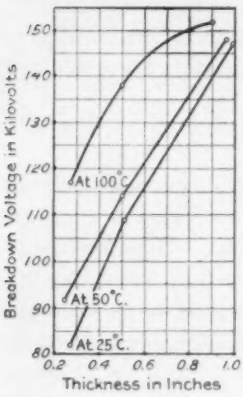

FIG. 5.—Dielectric strength of opaque fused quartz.

When crystal quartz or quartz sand is heated at a temperature above 1000°C it changes more or less rapidly into cristobalite and tridymite, if the temperature is not permitted to increase beyond 1700°C. However, by rapidly elevating the temperature to beyond 1700°C, the material is made to enter the vitreous state. If heating proceeds too slowly, quartz, which has begun to fuse, may be transformed into solid cristobalite or tridymite, which is then fusible at higher temperatures.

The transformation of quartz into the amorphous anhydrous product begins at 1470°C. The first signs of softening appear at 1650°C. It enters into plastic fusion at between 1750° and 1800°C.

The volatilization of silica begins at about 1650°C, except in the presence of carbon or hydrogen where it begins at 1250°C. In the latter case there is really a partial reduction and sublimation rather than pure vaporization. At 1800°C volatilization is very pronounced. The following data indicates the general order of magnitude of this effect (translucent quartz fusion).

Run	Temp °C	Time*	Loss %
1	1800	5 min.	1.0
2	2000	" "	20.5
3	2200	" "	38.3

The evaporation of silica in the production of clear quartz has a minimum of over 30%.[2]

[1] H. Helberger, *Zeits. fur Tech. Phys.*, **5**, No. 10.

[2] Thomson Research Lab., G. E. Co., H. L. Watson.

* Time held at maximum temp.

The silica does not become fluid at 1800°C, but only soft and plastic. However, if the temperature is rapidly increased to between 2000° and 2500°C the viscosity is considerably reduced so that the mass can be poured. These important temperatures can be tabulated as follows:

Formation of β quartz	575°C
Sublimes in presence of H or C	1250°C
Change to vitreous form starts	1470°
Begins to soften	1650°
Enters state of plastic fusion	1750°
Fused quartz is fluid above	2000°

At about 1400°C the small content of impurities which exists in amounts of about 0.2% in the purest silica (sand) commercially obtainable, will begin to show signs of weak fluxing activity and the mass will begin to cohere, even though the temperature is at least 450° below the theoretical melting point of pure silica.[1]

Latent Heat of Fusion of Quartz

The latent heat of fusion of vitreous silica has not been experimentally determined. Calculated values (Richard) (Vogt) indicate[2] it is about 64 to 66 gram calories per gram. It is, however, known that vitreous silica does not restore the heat of fusion in cooling; consequently fused quartz at low temperatures can be considered a liquid of extreme viscosity.

Physical Properties of Fused Quartz

A considerable mass of data has been accumulated indicating values for the more common properties of the amorphous anhydrous form of silica.

In the following, the word "translucent" refers to that variety of fused SiO_2 produced by the fusion of silica sand. This product is translucent except in large masses.

Specific gravity varies with homogeneity

[3]Translucent fused quartz 2 to 2.1

[2]Clear fused quartz 2.21 to 2.213

Thermal expansion (linear)

[2]Clear fused quartz t, 0–100°C, 49 x 10^{-8}

[4] " " " t, –190– 16, C x 10^4 = −0.0026

[4] " " " t, 16–500, C x 10^4 = 0.0057

[4] " " " t, 16–1000, C x 10^4 = 0.0058

[5]Translucent fused quartz t, about 25°C = .00000059

[1] J. Scharl and W. Savage, Commercial Development of Fused Silica.

[2] G. Flusin, *loc. cit.*

[3] Thomson Lab., G. E. Co.

[4] Smithsonian Institution.

[5] The Thermal Syndicate, Ltd.

Linear expansion determined using fused quartz tube fused onto fused quartz interferometer plates[1]

t,	26–83°C	58×10^{-8}
t,	83–177,	66×10^{-8}
t,	177–269,	66×10^{-8}
t,	26–966,	55×10^{-8}

Thermal expansion (cubical)

[1] Clear fused quartz t, 0–80C, 129×10^{-8}

The thermal expansion of glass of the more common types is 12 to 18 times that of pure fused quartz.

Specific heat, g. calories per g.

[2]t,	100°C	.204
[2]t,	500	.266
[2]t,	1000	.290

Mean specific heat

[2]t,	0–100	.1845
[2]t,	0–500	.2302
[2]t,	0–900	.2512

[2]Latent heat of fusion

64 to 66 g. calories per g.

Thermal conductivity g. calories per second per cc. per °C

[2]Translucent fused quartz		.002
[3]Clear fused quartz (sp. gr. 2.17)	(t 20°C)	.00237
	(t 100)	.00255

Hardness

[2]Silica glass (Mohs scale) 4.9

Fused quartz is harder than opal, [4] and some glasses, but softer than crystal quartz 5. 7, and hard (crown) glass, 6.2.

Volumetric Changes of Transformation of Crystallized to Vitreous Silica

[2]Quartz	to vit. silica	20. % increase in volume
[2]Tridymite	" " "	3.1 % increase in volume
[2]Cristobalite	" " "	5.4 % increase in volume

Permeability of Fused Quartz to Gases

Fused quartz at normal atmospheric temperatures and at low pressures is impermeable to gases. At higher temperatures it is permeable to certain gases.

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[1] Bur. Standards.

[2] G. Flusin, *loc. cit.*

[3] Smithsonian Institute.

[1]Hydrogen	diffuses	at 1000°C
Methane, Nitrogen, [1]Oxygen	diffuse	at 1300°C
[1]Helium	diffuses	at 300°C

[2]Hydrogen diffuses at 56 cm. pressure at 330°C
[2]N and O begin to diffuse at atm. pressure at 430°C

At temperatures between 700° and 1000°C the solubility of hydrogen in fused quartz is of the same order as that of hydrogen in water at 20°C, *i.e.*, .00160 g. per kg. at 760 mm. pressure.[3]

Chemical Properties of Fused Quartz

Acids Fused quartz is insoluble in all acids except phosphoric and hydrofluoric. Phosphoric acid combines with silica producing silicon phosphate.[3] Hydrofluoric acid combines producing fluoride of silicon or fluosilicic acid.

Comparative values indicating the speed of reactivity of hydrofluoric acid with various substances including fused quartz[2]:

Ordinary glass	1000
Fused quartz	100
Quartz parallel to axis	11
Quartz perpendicular to axis	1

Bases Fused quartz or vitreous silica is soluble in aqueous solutions of strong bases, as lithium, sodium, potassium, thallium, barium, strontium, calcium, and ammonium hydroxides; and in general in salts producing alkaline reactions. At ordinary temperatures the speed of reaction is so small as to generally escape observation. The speed of reaction rapidly increases with the temperature but depends also on time and concentration of the solvent. The following data[2] indicate the general order of reactivity of vitreous silica with various alkaline substances.

Temperature 18°C
90 sq. cm. SiO_2 in contact with reagent

Time (days)	Reagent	Concentration	Loss mm. gr.
2	NH_4 (OH)	10%	.8
2	NaOH	10%	.4
2	KOH	30%	1.2

[1] L. V. Hirschberg, *Zeits. für angewandte Chem.* (Berlin-Pankow).
[2] G. Flusin, *loc. cit.*
[3] Smithsonian Institution.

Time (days)	Reagent	Concentration	Loss mm. gr.
14	Na_2CO_3	1/N	.6
14	$Ba(OH)_2$	saturated	0.0
14	$Na(HPO)_7$	"	0.0
At 100°C			
Hours			
3	NaOH	2/N	33.0
"	KOH	2/N	31.0
"	Na_2CO_3	2/N	10.0

At high temperatures fused quartz is attacked by metals of the alkaline earth group. Tubes of fused quartz wound with nichrome wire are rapidly attacked at 900° to 1000°C. Silica is attacked by oxides of metals (at temperatures above 900°C) such as those of calcium and copper.

Annealing Fused Quartz

An examination in polarized light of clear fused quartz disks approximately 2 cm. thick and 7.5 cms. in diameter indicated that the specimens were highly strained.

Temperatures chosen for annealing tests on these samples were 1045°, 1070°, 1090°, and 1120°C. The annealing period was 2 hours. The cooling rate was started at 20°C per hour and increased so that samples could be removed from the furnace about 10 hours later.

After none of these treatments, with the possible exception of that of 1070°C was there a noticeable diminution in the strain evident by examination in polarized light. If any change occurred after treating at temperatures of 1090° and 1120°C these rough tests in polarized light indicated an increase in the strain.

"If strain results chiefly from inhomogeneities in the original crystals or differences between them before being fused together, no amount of ordinary annealing will reduce it. If the strain and inhomogeneity results from a tendency of the molecules while the glass is cooling through certain temperature ranges to reassume their alignment in the original crystals, then treatments which involve only low annealing temperatures and extremely rapid cooling through such ranges may aid in preventing these defects."[1]

Electrical Properties of Clear and Translucent Fused Quartz

The resistance of fused quartz is of the electrolytic order and consequently decreases with increase of temperature. At normal temperatures the volumetric resistance is of the order of 10^{19} of ohms per cm^3. The following tabulation indicates the specific resistance at various temperatures of both the clear and translucent varieties.

[1] Bur. Standards.

Ohms/cc. (volumetric resistivity)

Temperatures	Ohms	Temperatures	Ohms
[5]15°C (above)	4×10^{18}	[1]700	30×10^{6}
[2]25 (above)	1×10^{19}	[1](800)	(20×10^{6})
[1](150)	(2×10^{14})	[4](800)	(20×10^{6})
[3](150)	(2×10^{14})	[3](800)	(20×10^{6})
[1]230	2×10^{13}	[2]1800	2134
[1]250	25×10^{11}	[2]1950	189

[1]Ordinary glass is liquid at 1600°C, the resistivity being of the order of 0.1 ohm/cm[3]. Porcelain at 25°C has resistivity of 1×10^{14} ohms/cm[3]. which compares[2] to fused quartz at about 200°C.

Surface Leakage of Fused Quartz

Moisture does not condense on the surface of fused quartz in damp atmospheres; consequently it does not acquire the surface conductivity common with some insulation under similar circumstances.

The following data obtained at 25°C indicates leakage in amperes per cm. length at 500 volts d.c. with 1 cm. spacing between electrodes; of specimens of fused quartz and porcelain.

[2]At 50% humidity

Translucent fused quartz	(6 specimens)	2.1×10^{-11} to 6.7×10^{-12} amp.
Porcelain	(3 specimens)	5×10^{-11} to 7×10^{-12} amp.

[2]At 90% humidity

Translucent fused quartz	(6 specimens)	1.1×10^{-7} to 1.9×10^{-9} amp.
Porcelain	(3 specimens)	1×10^{-6} to 2×10^{-6} amp.

Dielectric Strength

The dielectric strength of fused quartz varies with the thickness of samples tested. In thin plates values have been obtained greater than 500 volts per mil.[6] The dielectric strength varies with the temperature. Tests of specimens under oil between 1 in. spherical electrodes, at various temperatures, produced the following results:[2]

Translucent fused quartz approximately $\frac{1}{4}$ in. thick.

Temp.	No. of breaks	Av. volts/mil.
25	8	298
50	7	410
100	5	397

[1] G. Flusin, *loc. cit.*
[2] General Engineering Lab., G. E. Co.
[3] Natl. Phys. Lab. (London).
[4] L. V. Hirschberg, *loc. cit.*
[5] Bur. Stand.
[6] Singer, Die Keramik, p. 297 (Braunschweig, 1923).

Translucent fused quartz approximately $\frac{1}{4}$ in. thick

Temp.	No. of breaks	Av. volts/mil.
25	6	203
50	4	230
100	5	238

Translucent fused quartz approximately $\frac{3}{4}$ in. thick

Temp.	No. of breaks	Av. volts/mil.
25	5	161
50	3	174
100	4	190

Translucent fused quartz approximately 1 in. thick

Temp.	No. of breaks	Av. volts/mil.
25	3	144
50	1	149
100	2	159

Tests made on porcelain at the same time the above data was obtained indicate that the dielectric strength of this material is considerably less than that of fused quartz at the same temperatures. Values tabulated for the dielectric strength of fused quartz are approximately 20% greater for $\frac{1}{4}$ in. material and 10% greater for 1 in. material than those obtained for wet process porcelain at 25°, 50°, and 100°C. Tests have been made that indicate that clear and opaque fused quartz specimens of similar form and under similar conditions have about the same values of dielectric strength at the same temperatures.

Dielectric Constant of Fused Quartz

Constant	Frequency	Authority
3.7		Bur. Stand.
3.5 to 3.6		Singer, *loc. cit.*
4.4	100,000	General Eng. Lab., G. E. Co.

The value 4.4 was obtained for a specimen of opaque quartz $\frac{1}{4}$ in. thick and 5 in. diameter, at 25°C, 60% humidity.

Dielectric Losses in Fused Quartz and Other Insulation

An insulating material of high resistivity and of great dielectric strength may be useless at high frequencies if it has high dielectric losses.

As shown in the following tabulation of data, the dielectric loss in fused quartz is less than in most comparable materials.

*Power losses in dielectrics.

(Temp. approx. 25°C)	C x 10^6
[1]Translucent fused quartz	0.57
[2]Clear fused quartz	0.94
Mica	0.47– 1.13
Paraffin	0.85– 3.02
Rosin	2.65
Porcelain	20.00– 30.00
Glass	10.00– 23.50
Bakelite	80.00–110.00
Pressboard	66.00
Rubber	77.50
Enamel of wire insulation	33.00

* The dielectric losses are proportional to a characteristic coefficient of the material, to the frequency and to the square of the electric field, or,

$W = CF^2f$, where,

W = the power loss per unit volume, watts/cm^3.

F = the electric field, kilovolts/cm.

f = the frequency in kilocycles.

Phase Difference, Power Factor, Loss Factor

Tests made on a specimen of translucent fused quartz 5 in. diameter and $\frac{1}{4}$ in. thick resulted in the following values:[1]

Power factor (%)	K	Loss factor
0.13	4.4	0.57

K = dielectric constant.

The phase angle of a specimen of clear fused quartz was found to be less than 20 seconds, this value being the limit of the measuring apparatus.[3] Some comparative tests made on specimens of clear and translucent fused quartz resulted in data indicating that the clear variety has a higher power factor than the translucent; furthermore, the clear specimens tested varied in value of power factor obtained, in a series of tests covering a period of several weeks, from 0.43 to 0.21%. The translucent specimen was $6\frac{1}{4}$ in. diameter and $\frac{1}{4}$ in. thick. The clear specimen measured 8 in. x $7\frac{1}{2}$ x $\frac{1}{8}$ in. thick. Data obtained follows:

	Date	PF (%)	K	PF×K
Translucent	Nov. 21, '24	0.13	4.4	0.57
"	" 29, "	0.13	4.4	0.57
"	Dec. 1, "	0.13	4.4	0.57
Clear	Oct. 9, "	0.43	4.5	1.94
"	Nov. 24, "	0.29	4.2	1.22
"	" 25, "	0.27	4.2	1.13
"	" 26, "	0.23	4.2	0.97
"	" 28, "	0.23	4.2	0.97
"	" 29, "	0.23	4.2	0.97
"	Dec. 1, "	0.21	4.2	0.88

PF = power factor. See definition in Supplement.

K = dielectric constant

PF×K = loss factor

[1] Gen. Eng. Lab., G. E. Co.

[2] P. Bouvier, *Radio Electricite*, **5** [51] (1924).

[3] Bur. Standards.

Tests were made at 100 kilocycles, 60% humidity, 25%C.

Mechanical Properties of Fused Quartz

Ultimate Strength in Compression

The end conditions of test specimens greatly affect the crushing strength of fused quartz. Tests in which soft sheet lead, paper, paraffin, and vaseline were used to cause uniform distribution of pressure, indicated that vaseline was the most effective of substances tried. "In the case of vaselined ends the failure was accompanied by a loud report and complete disintegration of the specimen into fine powder. With other materials the specimens were broken into large fragments. A specimen which withstood a lower load would break into fragments fewer and larger than the fragments from the specimens which withstood higher loads."[1]

In the following tabulation the lower values were obtained on specimens whose flat ends were not exactly parallel; the difference in the length of any specimen at different places being as much as .002 in. The length of test specimens was 1.5 in.; the ends were vaselined; the diameters varied from .397 to .547 in.

Specimen	Ultimate Strength (lbs./sq. in.)	Specimen	Ultimate Strength (lbs./sq. in.)
1 (diam. .547 in.)	191000	4 (diam. .510 in.)	148000
2 (diam. .509 in.)	154000	5 (diam. .510 in.)	114000
3 (diam. .508 in.)	156000	6 (diam. .397 in.)	97000

The compressive strength of fused quartz is probably greater than 191000 lbs./sq. in., the largest observed value. It is 3 or 4 times that of hard porcelain. Some comparative values follow:

Specimen	Ultimate Strength (lbs./sq. in.)
[2]Granite	20200
[2]Marble	12600
[2]Limestone	9000
[2]Sandstone	12500
[3]Hard porcelain	56300

The modulus of elasticity of fused quartz in compression is about 9400000 lbs./sq. in. (Determined by optical extensometer.)[1]

Ultimate Strength in Tension

Values for tensile strength of fused quartz tabulated in the following were obtained with the ends of specimens roughened with emery powder and inserted into closely fitting brass tubes filled with De Khotinsky cement. In order to apply an axial load to specimens, thin steel strips

[1] Bur. Standards.
[2] Smithsonian Institution.
[3] Singer, *loc. cit.*

were secured in slots in the outer end of each tube, so that the load caused tension in the strip. The strip was carefully centered with the axis of the specimen. Pins which passed through holes in the outer end of each strip were loaded by the testing machine. As the line connecting the centers of the two holes coincided with the axis of the specimen, the loading was nearly axial.

"It will be noted that the observed tensile strength decreases with increase in the diameter of the test specimen. This is probably due to the effect of non-uniform loading of specimen, which is becoming more and more difficult to obtain with the increase of the diameter of specimen."[1]

Specimen	Diameter	Tensile strength lbs./sq. in.
Clear	0.250 in.	6950
"	.343	3290
Opaque	.392	2650
"	.398	1610

Modulus of Rupture in Torsion

The following values listed for the torsional strength of fused quartz were obtained using an Amsler-Laffon torsion machine of 15 m. kg. (109 ft.-lb.) capacity reading to 0.001 m.k. (0.07 ft.-lb.) Sealing wax was used to hold the specimens in cylindrical holders.

Specimen	Diameter	Length of specimens between holders	Modulus og rupture lbs./sq. in.
Clear	0.565 in.	3.69 in.	6760
"	.544	3.00	6870
Opaque	.405	10.00	2300

Transverse Strength of Fused Quartz

Transverse tests on fused quartz specimens were made under conditions of a single beam loaded at two points in the middle.[1]

"Steel blocks 0.25 in. long, fitting the cylindrical surface of specimens were used at the supports and for applying load. The supporting blocks were resting on the knife edges and the load was transmitted to the loading blocks also through knife edges. The surface of specimen in contact with the loading and supporting blocks was covered with grease. These and other precautions taken were apparently sufficient to secure a proper distribution of load, as all of the tested specimens broke near the middle of the specimen and the appearance of the fracture was very similar in all cases." The deflection was measured by a dial reading by estimation to 0.0001 in.

Values listed in the tabulation for the modulus of rupture and modulus of elasticity were computed using the formulas stated in the following:

[1] Bur. Standards.

[1]Modulus of rupture $= \frac{Pda}{4I}$

[1]Modulus of elasticity $= \frac{P/I}{L} \times \frac{a(3 \times l^2 - 4a^2)}{48}$

where,
P = the total load (lbs.)
d = diam. of specimen (in.)
I = moment of inertia of cross section (in.^{4})
L = deflection in the middle (in.)
l = distance between the supports (5.5 in.)
a = distance from the point of application of load to the support (1.75 in.)

Specimen	Diameter	Mod. R*	Mod. E*
Clear	.575	10800	12660000
"	.455	9480	10550000
"	.507	9180	10330000
"	.503	8410	11840000
"	.561	7070	10840000
Opaque	.387	5390	11400000

* Mod. R = Modulus of rupture lbs./sq. in.
Mod. E = Modulus of elasticity lbs./sq. in.

The higher values shown in the preceding tabulation were obtained for unground specimens.

Optical Properties of Clear Fused Quartz

Transmissibility to Radiation

Clear or transparent fused quartz is very transparent to ultra-violet radiation of wave lengths longer than 0.193 μ.[2]

In some experiments on the absorption of ultra-violet radiation in fused quartz specimens of various thicknesses, it was determined that 1 inch of this material will transmit perfectly radiation as low as 2300 Å units; four inches of fused quartz transmits as low as 2500 Å and absorbs radiation of shorter wave length; 8 inches has for its lower limit the line 2536 Å and 11 inches stops all radiation below 2650 Å units.[3]

A fused quartz mercury arc lamp, grating spectroscope, and accessory apparatus were used in tests resulting in data given in the following tabulation. Special plates were not used.

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[1] Bur. Stand.
[2] G. Flusin, *loc. cit.*
Singer, *loc. cit.*
Phys. Zeit., **25** [15] 374–76 (1924).
[3] Thomson Research Lab., G. E. Co.

Absorption of Ultra-violet in Fused Quartz

Length of specimen	Exposure in seconds	Lowest line identified (in angstrom units)
0	35 sec. (*)	2299[1]
1	"	2299
$2\frac{7}{8}$	"	2464
$3\frac{15}{16}$	"	2464
$7\frac{7}{8}$	"	2536
$10\frac{7}{8}$	"	2657

(*) Lowest line identified through air only.

M. von Schwartz has stated as his conclusion, resulting from consideration of measurements made by George Joos, that only fused quartz produced by Hugo Helberger's process is capable of passing ultra-violet radiation of short wave length, presumably below 2400 Å units.[2] However, George Joos reports his belief that the negative results of other experimenters in measurements of the transmission characteristics of fused quartz at low wave lengths, may be due to a discontinuity in the spectrum of the quartz mercury lamp.[3] It is also apparent that the type of photographic plate employed is important.

In the literature among quantitative measurements are those of Pfluger, that a plate 2.81 mm. thick passed only 56% at 2100 Å and none under 2000 Å. However, in some experiments on the transmission characteristics of fused quartz, George Joos photographed the copper spectrum through fused quartz plates 6 mm. thick and obtained results indicating no absorption above 2000 Å and only moderate absorption at 1980 Å. Halbschuhman photographic plates made according to van Angerers directions were used.

Flusin[4] states that absorption is complete at 1930 Å but does not give the conditions of his experiment.

Clear fused quartz is completely opaque to infra-red radiation of 108 μ wave length, whereas silica in the crystal form is transparent.[5]

Specimen	Thickness (cm.)	Wave Length	Transmission (%)
Clear fused quartz	3.85	108μ	0
Parallel to axis	2.00	"	62
Transverse to axis	2.00	"	81

Refraction and Dispersion

The index of refraction of fused quartz at wave lengths corresponding to the position of the Fraunhofer lines *D*, *C*, and *F* is,[4]

[1] H. P. Hollnagel, Thomson Research Lab., G. E. Co.

[2] M. von Schwartz, "Fused Quartz Free of Bubbles," *Phys. Zeits.*, Aug. 1, 1924.

[3] G. Joos, "The Transparencey of Quartz Glass," *Phys. Zeits.*

[4] G. Flusin, *loc. cit.*

[5] Smithsonian Institution.

Index	Line	Wave Length
1.4585	*D* (Na)	5896.155 Å
1.55093	*C* (H)	6563.045
1.55899	*F* (H)	4861.527

The mean dispersion is therefore $1.55899 - 1.55093 = .00806$, and the optical constringence, $1.4585 - 1/.00806 = 56.8$. Tabulating we have,

Index of refraction Na line D.	1.4585
Mean dispersion	.00806
Optical constringence	56.8

The Comparative Values of Fused Quartz and Porcelain in the Construction of Electrical Insulation

Fused quartz and porcelain are similar in that they are slowly attacked by basic reagents but insoluble in nearly all acids. Both are attacked at high temperatures by metals of the alkaline earth group and by oxides of metals. Both materials are very resistant to abrasion and corrosion by exposure to weathering influences. They are not easily reduced in the presence of carbon or reducing gases even at temperatures near their softening points.

As indicated in the preceding tabulation of data the resistance of one centimeter cross-section of fused quartz 1 centimeter long, is equal to that of 1 centimeter cross-section of porcelain 1000 meters long, *i.e.*, the resistivity of fused quartz is 100,000 times that of porcelain, (at 25°C).

Fused quartz has at least five times the specific resistance of new hard rubber, which material has been recommended for years as the most satisfactory substance obtainable for use in the construction of low loss apparatus in radio engineering. Some comparative values follow:

Specimen	Volume Resistivity Megohms-cms.	Specimen	Volume Resistivity Megohms-cms.[1]
Fused quartz (above)	5×10^{12}	Rosin	5×10^{10}
New hard rubber	1×10^{12}	Paraffin	1×10^{10}
Clear mica	2×10^{11}	Shellac	1×10^{10}
Sulphur	1×10^{11}	Porcelain	3×10^{8}
Amber	5×10^{10}		

The dielectric strength of fused quartz at temperatures between 25° and 100°C is from 10 to 20% greater than that of porcelain under the same conditions. As has been shown the dielectric strength of fused quartz may reach 500 volts per mil. (in thin plates). However, purified asphalt in thin films (0.5 mm.) has dielectric strength of 2400

[1] Smithsonian Institution.

volts per mil.[1] Bengal mica has dielectric strength in plates 0.1 mm. thick as high as 5000 volts per mil.[2]

As has been shown in the preceding, the dielectric losses in fused quartz are lower than in most comparable materials.

The best known property of fused quartz is its great resistance to thermal shock. This is, of course, due to the very low coefficient of thermal expansion. At temperatures between 0° and 1000°C it is less than that of any other known substance, The linear expansion of porcelain is about 0.3×10^{-5}; more than 10 times that of fused quartz. Since electrical insulation may be exposed to thermal changes and thermal shocks of considerable magnitude it is apparent that fused quartz should provide better performance than any other ceramic material in this service.

The mechanical strength of fused quartz in torsion and tension compares with that of other ceramics.[3] In compression, the ultimate strength under favorable conditions is many times that of other ceramics. The material, however, is nearly as brittle as glass, and is greatly affected by small variations in conditions of loading.

Conclusions

Fused quartz has greater electric resistance than any other known substance at equivalent temperatures. It has lower thermal expansion than any other insulation, and consequently has greater resistance to thermal shock than porcelain or other ceramics. The compressive strength is greater than that of any comparable substance, (the material is, however, brittle and glass-like; consequently the maximum strength can probably not be utilized in practice). It is non-hygroscopic and furthermore highly resistant to corrosion and abrasion.

Both clear and translucent fused quartz are essentially homogeneous and uniform materials. The qualities enumerated in the preceding are very constant.

No damage results (to insulators) in the case of over-voltage surges on lines protected by fused quartz insulation. "The heat of an arc playing over its surface neither makes it a conductor nor splinters it."[4]

This property of resistance to intense electrical discharges is the result of the combination of the several peculiar physical properties of this material in one substance. The high melting point prevents change of form through the application of high temperatures for short

[1] G. Flusin, *loc. cit.*

[2] Smithsonian Institution.

[3] High Voltage Engineering Lab., G. E. Co.

[4] Elihu Thomson, Properties of Fused Quartz.

periods of time. High internal radiation causes the dissipation and distribution of heat applied at one point. The low expansion provides resistance to the effects of rapid temperature changes.

The dielectric strength and surface leakage characteristics are such that insulation can be given a thickness sufficient to render it puncture proof for any voltage desired. In this connection it may be remarked that porcelain can be produced in sections of moderate thickness only.

In applications where the qualities enumerated in the preceding are important, fused quartz is the best material available for electric insulation.

From the preceding data, it is evident that silicon-dioxide possesses some very unusual properties, among which may be mentioned: the piezo-electric effect of the crystalline variety, high transmission of ultra-violet light as applied to the mercury vapor lamp, and the low losses of translucent fused quartz at high frequency. A careful examination of the fused quartz varieties discloses many unique properties, and it is felt that a detailed study of these data will result in a wide field of application and utility.

Supplement

Dielectric Losses in Insulation of Alternating Current Circuits

Each mass of dielectric material or insulation between conductors in every alternating current circuit functions as an electrostatic condenser. In an ideal condenser the conducting parts have zero resistance and the dielectric (insulation) has infinite resistance. On application of an alternating e.m.f. to a perfect condenser, energy will be stored by electric displacement of the dielectric while the voltage is increasing, and will be released while the voltage is decreasing. When the e.m.f. is a maximum no current will flow, and when the e.m.f. is zero the current will be a maximum. In a perfect condenser the current and voltage are therefore 90° out of phase. However, in the case of actual condensers in which material insulation is employed as the dielectric, the conditions stated above are not fulfilled. As a consequence, an alternating current flowing in an actual condenser is never exactly 90° out of phase with the impressed voltage. The difference between 90° and the actual phase angle is therefore called the "phase difference."

In an ideal condenser, as the conditions stated show, there could be no consumption of power. The existence of a phase difference consequently means a power loss, which appears as a production of heat in the condenser. The amount of the power loss, in any case, is given, as for any part of a circuit by,

$P = E\ I \cos \phi$, where,

ϕ = the phase angle between current and voltage
$\cos \phi$ = the power factor
E = the effective e.m.f.
I = the effective current.

The preceding expression is equivalent to

$P = E\ I \sin \chi$, where,

χ = the phase difference
$\sin \chi$ = the power factor.

The phase difference is small except in the case of very poor insulation; therefore, $\sin \chi = \chi$ and the phase difference and power factor are synonymous. The power loss in a condenser is then,

$P = \omega\ C\ E^2 \sin \chi$ where,
$\omega = 2\pi \times$ frequency
C = electrostatic capacity.

The power loss is, therefore proportional to the frequency, to the capacity, and to the power factor.

Power Factor

Insulation may cause power loss by current leakage, by brush discharge, or by the phenomenon called dielectric absorption.

When a condenser is connected to a source of e.m.f. the instantaneous charge is followed by a flow of a small and steadily decreasing current into the condenser. The instantaneous discharge of a condenser is followed by a continually decreasing current. The phenomenon is similar to viscosity in a liquid and therefore is sometimes called "dielectric viscosity."

The power factors of solid dielectrics are generally due to dielectric absorption. Dielectric absorption is, as already stated, always accompanied by a power loss which appears as a production of heat in the condenser. The existence of a power loss indicates a component of e.m.f. in phase with the current. The effect of absorption is therefore equivalent to that of a resistance either in series or in parallel with a condenser.

A resistance in a condenser in series with the capacity affects the power factor very differently from a resistance in parallel. The e.m.f. across the resistance is in phase with the current while the e.m.f. across the capacity is 90° behind it in phase. The power factor equals $\sin \chi$ and since χ is usually small it may be taken as $\tan \chi$ which is equivalent to $r\omega C$.

If $r = 1$ ohm and $C = 0.01$ microfarad, the power factor at 60 cycles $= 3.8\ (10)^{-6}$ which is entirely negligible. However, at a frequency of, for instance, 1,000,000 cycles, the power factor $= 0.063 = 6.3\%$ which is large enough to be serious.

It has, therefore, been found convenient to represent absorption in terms of series resistance. An absorbing condenser is therefore considered from this point of view and the power factor is $r\omega C$.

The power loss in an insulating material is measured by a determination of the effective resistance or equivalent series resistance of a condenser made up of the material. The measurement of resistance may be made by either the resistance variation or reactance variation method.

When the power factor is due entirely to dielectric absorption the effective resistance decreases in proportion to an increase in frequency. The variation of power factor and the equivalent resistance with frequency is a complicated matter the laws of which are not accurately known. To a first approximation, however, the power factor of an absorbing condenser is constant.

Dielectric Constant, Specific Inductive Capacity

The specific inductive capacity is the ratio of the inductive capacity of the substance to that of a standard substance and therefore is a number.

An insulator is thought to contain no free electrons. The electrons are considered bound to the molecules in such manner that they can be slightly displaced by an electric force but return to positions of equilibrium when it is removed. This motion of the bound electrons, with the electric strain in the ether itself constitutes the electric displacement in the insulator and determines its constant.

Capacity[1]

When the two conducting plates of a condenser are parallel, close together, and of large area, the capacity of the condenser is given by,

$$C = 0.0885 \times 10^{-6} \frac{K\ S}{t}, \text{ where}$$

C = microfarads
S = area of one side of one plate in cm.^{2}
t = thickness of dielectric in cm.
K = the dielectric constant (air = 1)

[1] J. H. Morecroft, Principals of Radio Communication. Bur. Stand., *Circ.*, No. 74.

CONTINUITY IN PLASTIC BODIES[1]

By H. Spurrier

ABSTRACT

Extended experiments have shown that the plasticity of a clay increases with the growth of algae in it and the presence of hydrogel of alumina caused by a biochemical reaction. Air included in a clay body causes shortness. Experiments were run in evacuating the air in a clay and then by suddenly breaking the vacuum, collapsing the evacuated clay. The clay thus treated shows greatly increased plasticity, reduced warpage, elimination of blistering and resistance to rupture on distortion. The physics and chemistry of making clay plastic are discussed.

In presenting this contribution on the continuity of plastic bodies it may be as well to state that in an extreme sense nothing is strictly continuous. But we still refer to physical continuity in a gross sense, which implies absence of physical change as observed by our unaided senses.

Becoming interested some years ago in the physical changes wrought in plastic bodies by the mechanical processes to which they are subjected, the writer made a series of experiments, first upon the effects produced in clay bodies by pugging.

A method was developed for the determination of the amount of gases occluded in plastic bodies and the analysis of the liberated gases. The analysis of these gases showed that chemical change took place in the air occluded. Experiment was carried on with as great a continuity as other duties would permit and after about two years, the solution of the problem was found. It was discovered that under suitable conditions a specimen of clay might give off carbon dioxide and carbon monoxide almost indefinitely and that the reaction depended on a suitable supply of fresh oxygen and moisture, and finally that it was biochemical in character.

The biochemical action was found to be dependent upon algal metabolism. An attempt was made to identify the alga or algae involved. It was found that representatives of all the four main varieties of algae might occur at various times under suitable conditions: (1) cyanophyceae or blue-green algae, (2) chlorophyceae or green algae, (3) phaeophyceae or brown algae, and (4) rhodophyceae or red algae.

The most common varieties found in oxygen-fed slips were representatives of the chlorophyceae or green algae. Coincident with and probably consequently upon the growth of the algae in clay, the plasticity increases and at the same time considerable gas is evolved. If a clay slip is tested for alumina, soluble in dilute alkali, before and after the growth of algae with its consequent increase in plasticity,

[1] Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga., Feb., 1926. (White Wares Division.)

it will be found that more alumina is yielded to the dilute alkali in that slip in which there has occurred the greatest algal growth.

Assuming that the algae effected this separation of the silica and alumina, a direct experiment was made to produce the same effect in a direct and more rapid manner, the result of which was very interesting and of immediate industrial importance. For this purpose one-half per cent of hydrogel of alumina was added to a clay body which had been injured by too high a drying temperature and it was found that so small an addition immediately increased the plasticity of the clay in a marked degree.

It is known that plastic clays cannot be completely dried without some loss of plasticity and this is due largely, if not entirely, to the dehydration of the small content of hydrogel of alumina. Very commonly, a sample of plastic clay, dug moist from the earth, suffers a loss of plasticity on drying at a temperature below 100°F. Of course it is well known that the gelatinous hydrate of alumina precipitated by means of ammonia, cannot be dried without losing its gel character. Moreover it is known that long boiling makes it so gelatinous that it becomes exceedingly difficult to filter.

Physics and Chemistry of Making Clay Plastic

Shortness Due to Air

Filter press cakes are usually nearly or entirely air free when fresh, but the operation of pugging invariably introduces air mechanically, more especially if the mill blades are not at the proper pitch and if the mill is not properly fed. Just dumping clay into the mill is a very sure way to injure and shorten the body by air inclusion. A pug mill should be fed in such a manner that air is not entrapped as the blades feed the clay down. This is very easy to accomplish. The great importance of this was not realized until it became possible to secure really air-free clay and if its importance were generally known, I doubt if any clay worker would ever tolerate aerated mixtures again.

To make pie-crust short, butter, lard, or some fatty substance is put in that prevents the water from knitting the particles too closely and then a lot of air is kneaded in making the body discontinuous. Precisely the same effect is produced in clay. In preparing clay for use, much more air is introduced than is usually realized and in addition during the aging of the body, more gases containing carbon dioxide are generated, which in a measure offset the good effect of the aging. Moreover, carbon dioxide has a tendency to shorten clays in other than purely physical ways.

Method of Evacuation of Air

Many experiments were performed for the purpose of evacuating clay bodies, with varying success. Sometimes the body would be improved and at

others it was distinctly injured and a good deal of work was done in attempt to find out the cause or causes of these varying and disconcerting results. Not much headway was made until more careful studies were undertaken, using a mercury column to determine the degree of vacuity and a volumeter to indicate initial and final volume.

By exhausting clay under kerosene, the actual air removed could be measured and it now became obvious that the expected diminution of volume was not being secured. An effort was then made to collapse the evacuated clay by suddenly breaking the vacuum and this immediately gave results that were gratifying. Subsequent experience has shown that as the degree of vacuity has increased and the vacuum break made more sudden, better results have been secured and the last inch of vacuum is found to be the most important of all.

The apparatus now being used for this purpose realizes a vacuum in daily practice within $\frac{1}{2}$ to $\frac{5}{8}$ inch of atmosphere. This is checked by a barometer. Vacuum gages have been dispensed with as entirely unreliable and only a mercury column is used to indicate the vacuum. The vacuum, after reaching within $\frac{1}{2}$ inch of atmosphere, is maintained for 15 minutes and then broken suddenly (by a quick opening lever peet valve). The results are exceedingly gratifying. Benefits are secured which were quite unexpected both in nature and degree. Very extended experience has shown that in order to realize the full benefit of a highly evacuated body, it is absolutely essential to break vacuum with extreme suddenness and that the area of the vacuum break be as large as is practicable.

To this end a special vacuum break has been designed, which will open an area duly proportioned to the size of the evacuation chamber with a trigger device, which opens a plurality of ports with extreme suddenness. This device has very greatly improved the results of the operation and has presented conclusive proof that the collapsing of the evacuated vesicles by the sudden air impact is the determining factor in the process.

During evacuation it is found that there is a loss of water amounting sometimes to one-half per cent. It would be anticipated from this that the body would be a little firmer, but in practice it is found to be very considerably firmer and requires much more pressure to effect distortion, so much so that it was believed that a considerable loss of water had taken place. Repeated determinations have never shown a loss of over one-half per cent of water.

The plasticity of the evacuated product is so greatly increased, even in normally short bodies, that my veracity has been frequently questioned by those who have examined the unevacuated and evacuated material, cut from the same block of clay.

It very frequently happens that bodies formed by mechanical means suffer a distortion after forming, owing to the release of pressure and consequent readjustment of the contained air pockets.

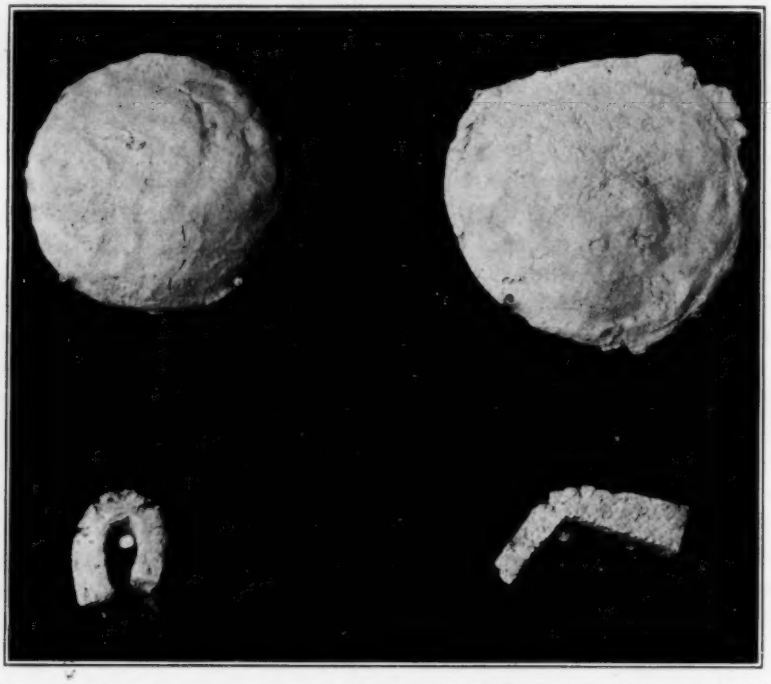

FIG. 1.—The upper part shows two balls of body referred to. That on the left is the evacuated and that on the right the untreated body after the drop test. The lower half of the photograph illustrates the two bars of body, the left being the evacuated and the right the untreated body. This piece broke at about 51° of bend; that on the left bent double or through 180° without breaking, and opened a little on drying.

It is a matter of common observation in the operation of pug mills and running out machines that the cross-section of the extruded body is noticeably greater than that of the die from which the body has been extruded, owing to the expansion of the contained air after its release from the working pressure of the mill. With evacuated clay this does not take place. Much blistering is, for obvious reasons, eliminated.

The resistance of the evacuated body to rupture on distortion is very greatly increased as will be shown by the following test:

A block of body was cut into two parts with a wire; one half was evacuated, the other being the while covered with a damp cloth. Two balls of exactly equal weight were made by approximately equal amount of handling, from the two portions of the body. The balls

were then dropped from a height of 17 feet onto a smooth surface and the areas were measured by an engineer's planimeter. The evacuated piece was rounded at the edges and showed no sign of cracking at all on the periphery. The unevacuated piece flattened out to a feather edge and cracked considerably, and showed 62% greater area than the evacuated ball.

Several tests for warpage on drying and firing have shown that warpage is reduced over 50%. In some clay wares, shrinkage is very important and here again a great advantage is gained. In a series of tests on bars, the shrinkage in the evacuated clay was absolutely uniform and somewhat less than in the unevacuated body.

The process is in daily use and has become standard practice. So greatly has the strength of the body been increased that those handling it for the first time made two or three grabs before they could detach a handful and then looked up in amazement asking what kind of clay it was.

It is interesting to know how large a block of clay can be successfully treated by the process and in what time. I am not in a position to give a definite answer to these questions, not having so far worked on masses larger than 12 inches through, but such pieces can be handled in 15 minutes successfully.

Many criticisms have been made of the process because of a failure to realize the magnitude of the forces brought to bear. If we have a 12-inch cube of clay in a cylinder evacuated to about 97% vacuum, we have a vacuum of 28.8 inches with the barometer at 29.7. Into such a chamber air would rush with a velocity of about 900 feet per second until the internal pressure had risen to 58% of the atmosphere; 900 feet per second is equal to more than 613 miles an hour and we have a mass of over 14 pounds per square inch impacting at this velocity. It may readily be seen that the compacting force is very large indeed. It is vitally necessary that the air inlet valves should be large and opened with great suddenness.

A mass of very plastic clay, by crutching in a lot of air, is enormously reduced in apparent plasticity and this is just what happens very commonly. If such an air-laden clay be subjected to a high vacuum, a considerable distention of the body takes place at first; next the greatly extended air vesicles begin to burst and the occluded air finds its way out of the body with increasing ease, as more and more bursting bubbles open a path toward the surface. The result of this is a cellular mass of clay, the cells of which are vacuous, but for the water vapor contained in them. At this high degree of vacuity the water is nearly at its boiling point and consequently gives off vapor very readily, thereby expelling a a larger portion of the previously contained air than would be

possible if dry instead of moist evacuation were taking place. But since one volume of water will develop 1650 volumes of vapor at atmospheric pressure and furthermore since the volume of gas is inversely as the pressure, it will readily be seen how so small a loss of moisture, less than one-half per cent, can, under conditions of vacuity, expel practically all the contained air.

If this cellular mass is suddenly exposed to the impacting force of the 14.7 pounds at atmosphere, delivered, as it is, at the rate of over 613 miles an hour on all sides, it will readily be seen that the compacting force is very large. It is abundant to collapse the empty vesicles and bring their opposite sides into physical contact.

That this really does take place, the following demonstration may be cited: In a block of graphite crucible body, 13 x 13 x 15 inches was made a hole of $2\frac{1}{2}$-inch diameter, reaching to the center. The opening at the surface was well-kneaded together and a husky protective piece of the same body was well-kneaded over this. The block so prepared was then subjected to the treatment. On cutting the block open with a wire, we were not able to find even a slight line indicating where the hole had originally been.

NORTHWESTERN TERRA COTTA CO.,
CHICAGO, ILL.

HYDROGEN-ION MEASUREMENTS ON CLAY SLIPS[1]

By D. W. Randolph and A. L. Donnenwirth

ABSTRACT

A simple electrometric apparatus is described for determining the hydrogen-ion concentration of clay slips. Some measurements are given to show the relation between hydrogen-ion concentration and the properties of a clay and water mixture.

The effects of acids and alkalis on the properties of clay and water mixtures have received a great deal of attention because of the important relations of these effects to the manufacture of almost every type of clay ware. The addition of small amounts of acid or alkali affects the viscosity of clay slips and the way in which they act in the casting mold, and influences the plasticity and the dry strength of the dry clay. A means of examining the mechanism by which these changes are brought about is of interest to the manufacturer because in the means employed may lie a method of control of processes or of raw materials.

The accepted theory is that the properties of a mixture of clay and water are largely affected by the presence of colloidal material, and the study of such systems has followed the progress of colloid chemistry. The amount of colloidal material present in a clay and its "quality" largely determines the nature of the clay, while the acidity or alkalinity of the water is an important variable.

Numerous and often contradictory results are reported in regard to the effects of acids and alkalis of different strengths on the physical properties of slips and clay pastes. Evidently the action depends on many factors, such as the original condition of the clay as regards acid or alkaline content, the concentration of the clay in the water, the time of aging of the mixture, the strength of the added electrolyte, etc.[2] It would seem that a method for following the changes in acidity of the water portion would give information of value.

It is not the purpose of this paper to propose a means of slip control based on acidity measurements, or to point out ways in which these measurements may be useful but rather to describe a simple apparatus and to give some of the data we have collected in our experience with it.

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[1] Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga., Feb., 1926. (White Wares Division.) Received May 24, 1926.

[2] Leonor Michaelis, General Principles of the Effects of Ions in Colloids, 2nd Colloid Symposium Monograph, 1925.

The *p*H Value

When an acid is placed in water it dissociates more or less completely into ions and the effect of acidity is due to an increase in the concentration of the hydrogen-ion. Pure water dissociates slightly into hydrogen- and hydroxyl-ions and the H- and OH-ions are equal in concentration. When an acid is added to pure water increased concentration of the H-ion results, while the addition of a base increases the OH-ion concentration. The actual concentrations are represented by some such figure as 10^{-14} and the inconvenience of dealing with such a number is avoided by calling this negative exponent "*p*H." Thus the *p*H of a solution having a hydrogen-ion concentration of $10^{-2}N$ is 2, while the *p*H of pure water is 7. For an exact and detailed explanation reference may be made to Clark's book on the determination of hydrogen-ions.[1] This means of expressing the acidity or alkalinity of a solution has been highly developed and is in universal use among chemists both as a tool for research and as a means of control of industrial processes. Baking, canning, water supply purification, and leather tanning are among the industries that are familiar with the term *p*H and use it in everyday control of operations.

Determination of *p*H Value

Two methods for determining the hydrogen-ion concentration or *p*H are in use. One depends on the change of color of a standard indicator when added to the solution under examination. The resulting color is compared to that of a standard series of colored solutions. A clear liquid sample without turbidity is required which necessitates the filtration of the liquid from the clay. The electrometric method determines the *p*H by measuring the voltage set up between two standard electrodes when they are dipped into the solution. With care the electrometric method will give good results in thick clay slips and does not require special preparation of the sample.

The electrometric apparatus consists of two electrodes, one of hydrogen and the other of calomel. The hydrogen electrode is formed by the use of a layer of platinum sponge which is kept saturated with hydrogen gas. The calomel reference cell depends on the potential due to the equilibrium between mercurous ions and a mercury surface. The contact between this reference cell and the liquid under examination is made by means of a standard solution of potassium chloride. For a discussion of the theory of these electrodes, as well as complete and helpful directions as to their use, Clark's book is again referred to,

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[1] W. M. Clark, The Determination of Hydrogen Ions.

and only a description of the mechanical details of the apparatus will be given here.

Figure 1 is a sketch of the electrodes, as made by the Leeds & Northrup Company. Two hydrogen electrodes are used, either of which may be connected to the potentiometer by means of a two-way switch. This gives a rapid way of checking a reading. The center portion of each hydrogen electrode is removable for cleaning or replating and consists of a straight glass tube with a piece of platinum wire sealed through the end. Platinum black is plated on the exposed end of the wire by electrolysis in a dilute solution of platinic chloride, and just before use the electrode is placed in a dilute solution of sulphuric acid as the cathode and saturated with hydrogen gas. The platinum black coating adsorbs many times its weight of hydrogen and the result is a hydrogen electrode in contact with the sample. Continued use of this electrode in a clay slip renders the electrode inactive and when this occurs the center portion is removed and may be cleaned and replated in a few moments.

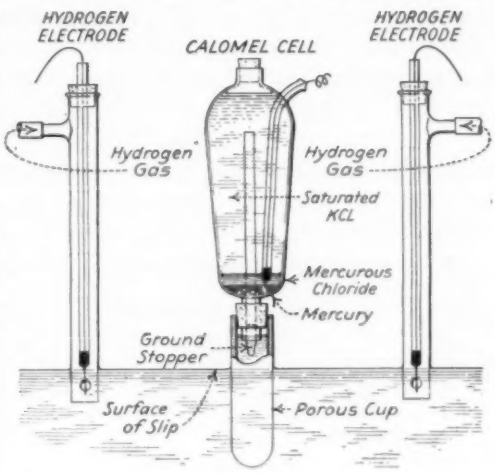

FIG. 1

The calomel cell is especially suited for use in clay slips because contact is made through a porous porcelain cup that prevents contamination of the cell by fine particles of clay. The cell is self-contained and there is no danger of dust entering. The KCL in the porous cup may be renewed easily if necessary, at which time the glass valve at the bottom of the cell prevents loss of solution from the cell itself.

All three electrodes are held in a support and may be inserted into a 400 cc. beaker which holds the sample under observation. A stirring paddle driven by a small motor is useful, and burettes may be mounted above the beaker for the addition of measured amounts of electrolytes. Hydrogen is supplied to the two hydrogen electrodes at a slow rate so that about one bubble of gas escapes from each electrode every second. We have used commercial tank hydrogen and have not found it necessary to purify the gas although this is very desirable. The measuring instrument must be of the

potentiometer type as no current can be drawn from the electrodes without affecting their reading.

Hall[1] has examined the effect of changes in hydrogen-ion concentration on the flocculation and deflocculation of clays and has also determined the *p*H of slips formed by various clays in water. He shows the effect of the presence of clay in water when an electrolyte such as NaOH is added. The amount of electrolyte adsorbed by the clay is shown by the lower hydrogen-ion concentration as compared to that resulting from the addition of the same amount of electrolyte to water alone. Hall concludes that, in the case of the clay he used, the action was a physical one until a *p*H of 12 was reached after which a chemical action set in.

Report of Observations

In Fig. 2 are shown some data obtained with two ball clays, Kentucky and English. We have used a water-clay ratio of 12 to 1, while Hall used a ratio of 70 to 1, which accounts for the much larger apparent adsorption shown in our measurements. These curves were obtained after a measured amount of electrolyte was added, the slip thoroughly stirred and then allowed to stand for 24 hours. The electrolytes used were acetic acid and sodium carbonate.

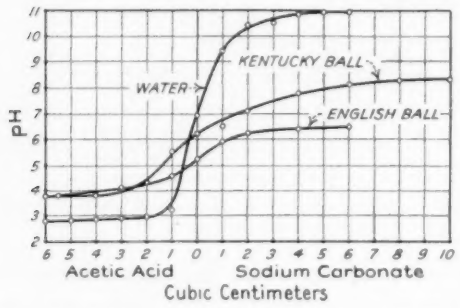

FIG. 2.—Adsorption of acids and alkalis by clays.

It is interesting to note that the adsorption of alkali is greater than the adsorption of acid, especially in the case of the Kentucky ball clay.[2] The initial *p*H of the slip is given by the intersection of the curve with the zero addition line. Evidently the English clay resists the action of the electrolyte that would tend to change the *p*H of the resulting solution more than the Kentucky clay. It should be noted that the difference is exaggerated by the fact that the English clay is more acid to start with than is the Kentucky clay.

The effect of the aging of a clay slip on its *p*H without the addition of electrolytes was investigated. Our results agree with those of Hall

---

[1] F. P. Hall, *Jour. Amer. Ceram. Soc.*, **6**[9], 989 (1923).

[2] Searle, The Chemical and Physical Properties of Clays and Other Ceramic Materials, p. 241.

in that no change of any magnitude could be found in the case of Kentucky ball clay, English ball clay, Florida kaolin, or Delaware kaolin after aging for periods of from two to three weeks. Further work that is not completed indicates that the adsorption of the electrolyte by clay increases in some cases with the length of time the slip has aged; that is, the addition of an electrolyte to the aged slip does not cause as large a change in H-ion concentration as the addition of an equal amount to a freshly blunged sample.

These results apparently indicate that the amount and character of the colloidal or finely divided matter in a clay are both important in determining the action of the electrolyte. It may be possible that clay from the same source, but from different parts of the bed will vary greatly in reaction to electrolytes, due to the variation in amount and character of the colloidal portion of the clay.

In our plant water is supplied from the city mains and is subjected to various purifying and settling processes before we receive it. For a period of time we kept a record of the variations in the *p*H of the water from the mains and also of the viscosity of a slip made from Kentucky ball clay and this water, in the proportion of 50 grams of dry clay to 300 cc. of water. The results of this experiment are shown in Fig. 3 and indicate the close connection between the slight changes in acidity of the water and the viscosity of the ball clay slip. These data are interesting because they show the source of a variation in slip viscosity that would call for more or less electrolyte to correct it. It also serves to emphasize the fact that the hydrogen-ion measurements are directly related to some of the properties of the slip.

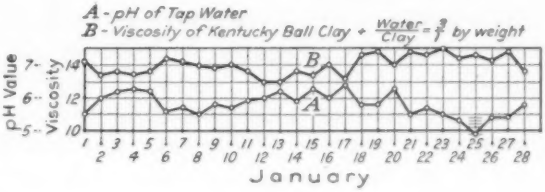
A - pH of Tap Water
B - Viscosity of Kentucky Ball Clay + Water/Clay = 3/1 by weight
pH Value
Viscosity
7
6
5
14
12
10
B
A
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
January

FIG. 3.

Schurecht[1] and others have called attention to the fact that the addition of electrolytes has an effect on the strength of clay pieces in the dry state. Schurecht mentions the use of sodium silicate, sodium carbonate, and calcium hydroxide in adding strength to a dry clay piece. In order to investigate this point we made up a series of batches of a spark plug body. The *p*H of successive batches was adjusted while the clay was in slip form in the ball mill. A number of bars were made up from each batch, dried under standard conditions, and the breaking strength of these bars was determined. Figure 4 shows

[1] H. G. Schurecht, *Jour. Amer. Ceram. Soc.*, **1**, 201 (1918).

the relation between the breaking strength and the *p*H of the slip. The addition of sodium carbonate in most cases would weaken this body in the dry state, since it naturally tends to lie somewhat on the alkaline side of *p*H 7. No difference could be detected in dry strength when an adjustment to a given *p*H was made by means of different electrolytes. One of the points at the maximum of the curve represents a body adjusted by means of acetic acid, another by the use of hydrochloric acid, and the third by the addition of sodium silicate to a batch that was first made acid by mistake. This tends to show that there is a definite relation between dry strength and the H-ion concentration of the water phase of the system. While in many cases the dry strength of a body is ample, still one explanation of periodic weakness and resultant loss in handling may lie in slight changes in the acidity of the slip, due either to differences in the clays used or to changes in the water supply.

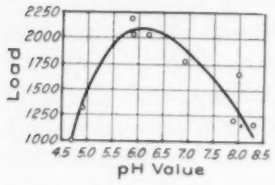

FIG. 4—Effect of *p*H on dry strength of spark plug body.

In the casting of clays the effect of slight changes in acidity or alkalinity are important; and changes in H-ion concentration rather than additions of a particular electrolyte by volume may explain some of the puzzling things that occur. For instance, a change in one of the clays used may make necessary the use of more or less than the usual amount of electrolyte for a time. Figure 5 shows the relation between the viscosity of a Kentucky ball clay and the *p*H of the water, through the range generally used in casting. Over a very short range the viscosity was the same at a given *p*H regardless of whether the electrolyte was sodium carbonate or sodium hydroxide on the basic side, or whether acetic acid or hydrochloric acid was used on the acid side. In the range of alkalinity beyond a *p*H of 10, however, this was not true; sodium hydroxide, for instance, producing a thicker slip than sodium carbonate. This is probably due to chemical action of some kind between the organic salts originally in the clay or to chemical action on portions of the clay itself. The English ball clay used in our experiments showed much less change in viscosity with changes in *p*H and the results in some cases were so erratic that we have not included this curve as there was no time to thoroughly check the results. Apparently, in the case of No. 25 English ball clay, there was a chemical action of some kind which took place at a *p*H of 4.3 that caused a decrease in viscosity

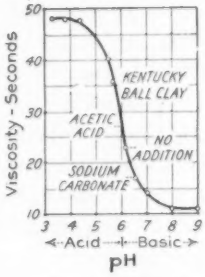

FIG. 5.—Viscosity –H-ion concentration. Water/clay = 2/1.

instead of the expected increase. The action on the basic side as far as a *p*H of 10 was normal. There is evidence that chemical action of some kind occurs in the case of all alkaline hydroxides at even very low concentrations. The relation between *p*H and viscosity is not a definite one for any particular clay and depends largely on the electrolyte used.

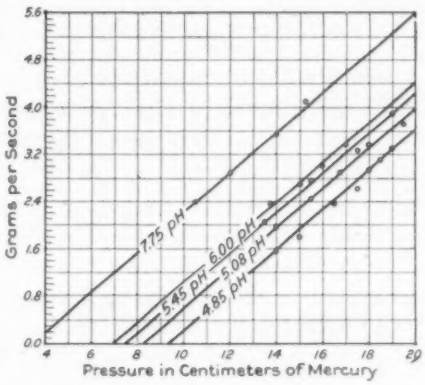

FIG. 6.—Kentucky ball clay–old mine No. 4. Bingham Plasticity Curve.

The effect of a change in *p*H on the plasticity of Kentucky ball clay as measured by Bingham's method is shown in Fig. 6. Bingham considers plasticity as dependent on two factors—mobility and yield point. Changing the *p*H of this ball clay does not change the slope of these curves, but the "yield value" or point of intersection with the axis of the curves changes in proportion to the *p*H value. This seems to hold for several clays, but it is probable that there is no very definite relation between *p*H and yield value when different electrolytes are used with the same clay.[1]

The measurement of hydrogen-ion concentration should be of value to anyone dealing with clay products made by either the plastic or casting process. It cannot be substituted for other means of control, but may prove extremely useful and an important help in dealing with clays in slip and plastic forms.

A. C. SPARK PLUG COMPANY
FLINT, MICHIGAN

[1] E. C. Bingham, Fluidity and Plasticity, p. 232.

FIRING TERRA COTTA IN AN OPEN KILN[1]

By O. E. Mathiasen

ABSTRACT

Tests on firing terra cotta in an open oil fired kiln are described. A full description is given of the special flue and combustion chamber design used in the kilns. Results of the tests were entirely satisfactory and justify further experiments along this line.

Very few known attempts have been made to try the practical possibilities of firing terra cotta, or for that matter any glazed ware, without a muffle or in an open kiln. In most tests the fuel used was gas, not coal or fuel oil. There has been quite some talk about firing terra cotta in an open kiln, but as far as we know, this is the first attempt on anything like a practical basis, using oil as a fuel.

Three separate firings were made. The first in a kiln at the General Ceramics Company, at their Keasbey plant through the courtesy of F. A. Whitaker, and the last two at the plant of the Carborundum Company, through the courtesy of E. B. Forse. The kilns in both cases were regular rectangular kilns with special flue and combustion chamber construction as designed by the Carborundum Company. B. M. Johnson of the latter Company delivered a paper before the New Jersey Clay Workers Association in which he described this special combustion chamber as follows:

The carboradiant combustion chamber in the form particularly adapted to kiln firing consists of two rectangular flues, one superimposed on the other, built up of relatively thin silicon-carbide tile as illustrated in Fig. 1. The extension of the lower section is built into the kiln wall and into this opening the oil is fired. The lower flue connects with the upper at the end away from the burner and the gases thus return toward the burner. The tile forming the top of the upper flue are spaced to permit egress of the gases along the entire length. These combustion chambers are placed on either side of the kiln space as illustrated in Fig. 1 and, depending on the length of the kiln, either two or four chambers are used requiring either two or four burners. Between the chambers and the ware being fired stands a thin permanent bag wall that serves three purposes: (1) to permit the combustion chambers to run hotter than the ware particularly during early firing, (2) to direct the gases of combustion to the top of the kiln, and (3) to offer a means of regulating the application of heat to the ware by variations in its construction.

The operation of these chambers is very simple. A small quantity of oil is discharged into the entrance, and the lower flue heats up rapidly so that good combustion is attained within a very few minutes. Then the proportion of excess air is reduced so that combustion takes place throughout the entire length of the lower flue. The upper flue rapidly reaches the temperature of the lower flue by contact with the hot gases and by transmission of heat through the thin tile forming the partition between the two. From this time the entire chamber is uniform in temperature from end to end because as the general temperature of the chambers is raised the radiation through the partition

[1] Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga., Feb., 1926. (Terra Cotta Division.) Recd. May 7, 1926.

tile compensates for the gradual loss in temperature of the gases during their travel through the two flues.

Control of the fire is maintained by observation through small peep holes in the wall of the kiln above the burners. Sufficient air is admitted with the oil to complete combustion within the chambers and observation of the exhaust ports on the top of the chambers indicates this condition.

Using this means of combustion offers a number of advantages in heat application and kiln operation, both equally important in ceramic processes. The chambers furnish a radiant heating element of uniform temperature from end to end of the kiln instead of a series of hot and cold spots from a number of fireboxes. By proper outlet spacing they distribute the gases of combustion uniformly along its length. In the construction of the bag wall even temperature from top to bottom of the kiln may be obtained, as the construction readily permits a number of variations through its walls in heat flow although for ordinary kiln heights the increased radiation through its lower portion compensates for the loss in sensible heat of the gases in their downward flow through the ware.

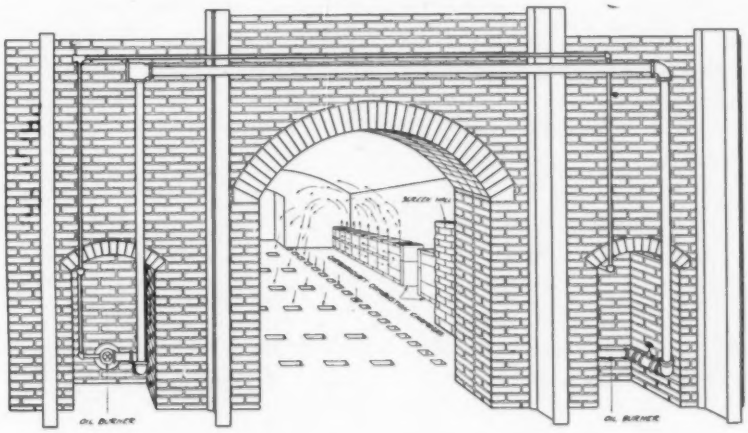

FIG. 1.—Carboradiant kiln—showing arrangement of chambers.

These chambers offer a simple means of visual control from a few burners, particularly for ware demanding regulation of atmosphere. Combustion can be maintained with either oxidizing or reducing conditions without sacrifice in efficiency. If flame is discharging from the outlet ports reducing conditions result, and if combustion is complete within the chamber the atmosphere is oxidizing. These conditions can be maintained without a great excess of air or dense volumes of smoke.

As a combustion device for oil the conditions furnished are ideal, as a temperature sufficient to support combustion is quickly reached. The small cross-section area of the flues gives an intimate mixing of oil and air. The long gas travel in contact with surface hot enough to support combustion permits the reduction of excess air to a minimum.

The rate of firing was typical of a small kiln, a slow increase for 10 hours then a straight line to complete the burn after about 60 hours

firing to cone 5 down. CO_2 readings varied from 12 to 14% during the run from about 10 hours to end.

The ware in kilns was typical of a terra cotta plant. Pieces of terra cotta of all shapes and sizes, colors of all polychrome shades, and all of our regular finishes, matt and full glazes, unglazed plain and speckled, spattered finishes, glazed and unglazed, all on both regular pieces and samples.

The first firing was very satisfactory; all colors were exact duplicate of results in a true muffle kiln.

On the second firing, through error in instructions, the operator overfired the kiln with the result that all glazes, etc. were overfired. We did not take any stock in the results of this firing as the final temperature reached was much higher than that usual for terra cotta.

The third and final firing was entirely satisfactory. All colors and finishes were their regular shades. There was one color, however, which did not duplicate itself in any of the firings. This is a spattered and spotted unglazed texture color with a ground coat containing a small percentage of red clay to give a pink tone. In the open fire, this pink tone was not nearly as pronounced as in a muffle kiln. A change in slip ingredients would probably remedy this.

Polychrome colors were satisfactorily uniform.

These tests were carried out solely to prove the possibilities of firing terra cotta in an open kiln. On account of the small size of the kiln little attention was given to oil consumption although it ran around 95 gallons per fired ton of terra cotta.

The results of these tests justify further experimenting in designing and adjusting kilns for firing terra cotta and other glazed wares in an open kiln with oil as the fuel.

New Jersey Terra Cotta Co.
Perth Amboy, N. J.

A NEW TYPE OF DRIER HEATER[1]

By Charles F. Geiger

ABSTRACT

A novel design of a combination air heater and combustion chamber burning liquid or gaseous fuel is presented and illustrated with a drawing. Desirable features of independent drier heaters are outlined, and the efficacy of the equipment described in approaching the ideal achievements is demonstrated. Mention is made of the application of this type of heater to a number of different processes as well as to the heating of factory buildings.

Introduction

In many plants an independent drier heater is either a necessary or desirable means of supplying heat for drying processes. An ideal self-contained heater to be satisfactory must, fundamentally, be economical of fuel and labor, and it must afford continuous service with minimum supervision and maintenance. The successful heating unit, moreover, essentially produces clean gases so as not to injure the ware or inject obnoxious fumes into the working buildings. It needs, also, possess simplicity of operation and construction as outstanding features and be sufficiently flexible to permit of considerable variation in the output of heated air supply.

It is believed that the drier heater to be described embodies to a high degree practically all the advantages of the ideal drier heater. Before passing to a description, however, it might be well to detail briefly some of the disadvantages of the particular system that the new heater was designed to supplant.

A single, coal-fired pit-furnace was formerly employed for each group of three double-track tunnel driers each of 114 feet length. An exhauster fan situated above the loading end of each three driers supplied the draft for the fireboxes and induced the flow of hot gases, air, and evaporated water through the driers to the stack leading through the overhead roof. This equipment though functioning entirely satisfactorily for drying purposes was inherently insufficient in several respects all of which either directly or indirectly exerted an influence on the cost of operation. Coal had to be hauled to the fireboxes and ashes removed. Drier firemen were necessary twenty-four hours a day throughout the year. A considerable quantity of soot was deposited upon the ware and in the drier tunnels; this had to be brushed from the ware to allow of subsequent treatment previous to setting. The driers—roofs, sides, and floors—had to be thoroughly cleaned every three or four months. The atmosphere within the driers, due to the imperfect combustion in the fireboxes, was at least unpleasant for drier

[1] Received April 7, 1926.

operators who frequently had to work within the tunnels as the congested situation of the driers did not permit of mechanical means of car propulsion. Another and one of the worst objections to the system was the fire hazard. Sparks from the fireboxes caused ignition of the wooden pallets and the greasy soot. These fires aided by the exhaust fan frequently gained tremendous headway before being discovered and caused heavy losses of ware and pallets, and even seriously damaged the motors driving the exhausters because the entire flue system, being soot laden, afforded ready propagation for flame travel all the way to and through the fans. Even though a fire were discovered in a relatively early development, damage caused by fire and water to twenty-eight large drier cars loaded with silicon-carbide refractories could readily run into several thousand dollars. Then again three or four fires of this nature meant increased insurance rates for the entire plant. It is easy to comprehend, therefore, that the system though entirely adequate as far as mere drying was concerned was insufficient when all costs and inconveniences were considered.

Description of Carboradiant Direct-Fired Drier

The drier heater installed consists of the very simple structure illustrated in the drawing. The shell, which is insulated, is built of fire brick; this surrounds the 8-foot combustion chamber which is made up of thin special-shaped, interlocking silicon-carbide tile to form a rectangular flue running parallel to the length of the shell. The burner feeds in through the front wall and combustion takes place throughout the length of the carborundum chamber; the supply of primary and secondary air is adjusted so that combustion is entirely complete within the silicon-carbide flue so that no flame can be seen issuing from the two outlets. As it becomes necessary to increase the rate of burning the oil, more air is supplied through or around the burner so that all combustion is still maintained within the chamber. The long travel of the gases within relatively narrow confinement necessitates complete mixture of oil-vapor and air. Because of the incandescence of the walls throughout the length of the carborundum chamber and the absolute control of the primary and the secondary air it is always possible to effect complete combustion within the firing flue so that no unburned gases are discharged from it.

The air to be heated is induced into the shell through the adjustable louvers in the front wall. The baffles compel the air to pass across the furnace providing a good wiping action against the incandescent chamber thereby affording an efficient heat transfer. The inner fireclay walls and crown of the shell are built with projections in alternate rows of brick; the latter are heated by radiation from the furnace and likewise transmit heat to the air passing their surfaces. The heated

air receives a further temperature increase on being mixed with the products of combustion issuing from the chamber just previous to the passage that leads to the header flue in front of the drying tunnels.

The louver in the flue beyond the heater is of use at those times when only a very small quantity of heated air may be desired or when the final air temperature is to be very low. In either circumstance the front wall louvers are closed, and the products of combustion are tempered as required with air entering the rear louver. It is preferable on very low air requirements to operate in this manner in order that the carborundum furnace may be maintained at a red heat so that complete combustion is facilitated. When a drier of this type is used for supplying hot air for spray drying food products or chemicals the gas outlet shown in the drawing is employed only for a very few minutes in starting up and during this time the damper in the flue leading to the drier is closed.

The oil from the main storage tank is distributed by a small gear pump requiring one-horse power. A low-pressure air-atomizing burner employing six ounce primary air has its air supply furnished by a small fan requiring three-horse power at maximum blower capacity of 600 cubic feet per minute which is about 300% over the amount required for normal operation of this particular unit. The secondary air is induced around the burner. The motor sizes are given to show the small amount of electric energy necessary to operate the equipment. The total cost of the electric power required by both motors is from 3 to $7\frac{1}{2}$ cents per hour.

Costs and Savings

A drier heater of this type costs two thousand to twenty-five hundred dollars completely installed, including all mechanical and electrical equipment, materials, labor, and erection costs. This heater operates on an oil consumption of 1.3 to 2.5 gallons per hour per drier depending upon the temperature desired. An average of 108 gallons of oil per day for three driers promotes faster drying than the ton of coal required per twenty-four hours with the old system. These figures demonstrate the efficiency of the oil-burning equipment, which also has none of the disadvantages formerly encountered. There is no soot whatever, and consequently the ware and the driers do not require cleaning. There is no smoke at any time, and, of course, coal and ash haulage are cost factors no longer. The important saving in operation, however, is the elimination of drier firemen. The system requires attention once every three or four hours only and this little work has been transferred to the tunnel kiln firemen. This saving is $12 per twenty-four hours or over $4000 per year so that the installation paid for itself in labor saving alone in approximately six months.

This heater has been operated for over two years and there have been no drier fires during that period. There is no firebox to burn out and only three or four tile have had to be replaced from breakage in 17,000 hours of practically continuous operation. Repairs to the shell are not anticipated as there is no flame impingement on the fire brick, which, incidently, barely reach a red heat.

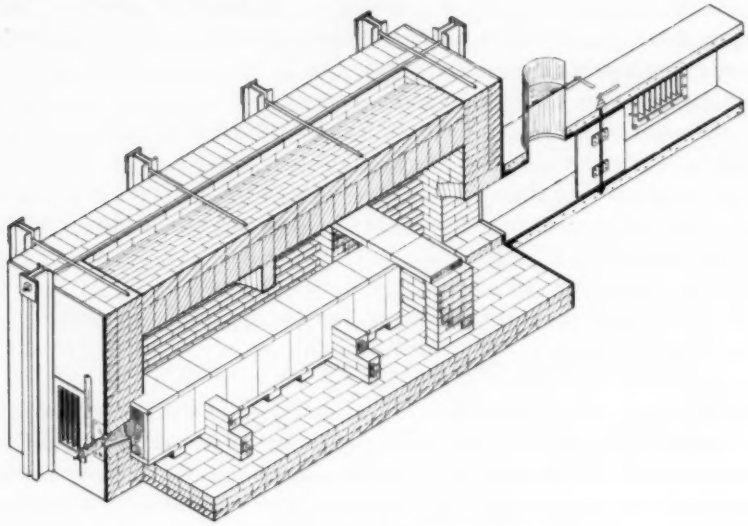

FIG. 1.—Carboradiant air heater—direct fired.

There seemingly is no reason why humidity drying with gas recirculation could not be coupled in many cases with this heating unit which obviously is more efficient in heat transfer than indirect steam heating.

The efficacy of the combustion chamber in producing complete combustion is demonstrated by the fact of the successful application of this method of heating air that is admixed with the products of combustion to the spray drying of such food stuffs and chemicals as baking soda, salt, Glauber's salts, and chrome tanning compound. This type of combustion chamber and air heater is being applied also to rotary driers. One of these heaters is being designed, also, for a combination of drying ceramic ware and heating factory buildings. In this case part of the heated air will be removed from the furnace previous to its admixture with the products of combustion. This is to be conveyed through ducts and discharged at sundry points for supplying heat to the building. The burned gases are to be mixed with air and this product will be used for the drying of sanitary ware.

THE CARBORUNDUM COMPANY
REFRACTORY DIVISION
PERTH AMBOY, N. J.

CERAMIC ABSTRACTS

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Abrasives

Pumice is prepared carefully. ANON. *Abrasive Ind.*, **7** [6], 183 (1926).—A description is given of the prepn. and selection of pumice as carried out on the island of Lipari in the Mediterranean. The article is illustrated with a number of photographs.

C. J. H.

Abrasive materials in 1924. F. J. KATZ. Bur. Mines, *Mineral Resources of U. S.*, **1924,** Part II, 241–52 (preprint No. 20, published Mar. 29, 1926). (*C. A.*)

Art

Black-figured vases. GISELA M. A. RICHTER. *Ceramist*, **8** [1], 19–26 (1926).—From a purely decorative point of view, the Athenian black-figured vases are often superior to the red-figured examples. They are nearer in time, spirit, and technique to the 7th century wares, when effective designs were considered more important than the content of the representation or its execution. When we compare the recently acquired black-figured vases with the red-figured ones previously on exhibition at the Metropolitan Museum of Art, New York, we find that in the latter the quality of the

drawing was the chief attraction, whereas in the earlier pieces we must look for the decorative impression of the whole compn. R. describes in detail the following examples of black-figured vases, giving photographs of the more important and pointing out the significance of the decorations. (1) A small Corinthian kotyle ($3\frac{1}{16}$ in. high) 1st half of 6th century B.C. (2) A deep kylix on a low foot, probably late Corinthian style. (3) A series of kylixes, 2nd half of 6th century and early part of 5th B.C. of the "Kleinmeister" type. (4) Several vases of the kylix type depicting daily life, including the only specimen of Epitimos' work that has survived. (5) A small lekythos. (6) A hydria. (7) An amphora ($13\frac{7}{8}$ in. high). (8) A column krater ($19\frac{7}{8}$ in. high). (9) A large loutrophoros ($29\frac{3}{16}$ in. high). (10) A lekythos and an alabastron showing the use of black figures on a white engobe. These Athenian examples are compared with a contemporary Etrusco-Ionian amphora. A. E. R. W.

Ceramic pigments of the Indians of the southwest. FRANK E. E. GERMANN. *Science*, **63** [1636], 480 (1926).—A study of the pigments used by the Indians to decorate their pottery has been made. From an early date they used two oxides of iron for the production of black and red pigment. They apparently knew something of the control of oxidation and reduction. C. J. H.

Probe thermal expansion in the flashing of cobalt blue on crystal. ANON. *Amer. Glass Rev.*, **45** [32], 17 (1926).—A report of W. E. S. Turner's paper on "The Flashing of English Crystal by Cobalt Blue Glass." Two sets of glasses were made up, one of soda-lime glasses and the other of potash-lead oxide glasses. Beginning with apparently colorless glass in each case, 3 or 4 other glasses were made up with gradually increasing amts. of cobalt oxide added for coloring. The thermal expansion of each of these glasses was measured by the differential expansion of the glass against a quartz rod. The effect of the cobalt oxide was to slightly modify the thermal expansion, the difference in expansion between the initial and the extreme glass being less than 5 % at any temp. where the rate of expansion was practically linear. In the case of the lime glasses the addition of cobalt oxide exercised a very slight softening effect while in the case of the lead glasses it appeared to exercise a slight hardening effect. The conclusions were that failure to weld cryst. and cobalt-blue glasses was not due to differences in thermal expansion, but probably to a difference in the rate of cooling off of the two glasses. The addition of cobalt oxide changed the mobility or viscosity of the glass so that the range of working was shorter and this must be overcome by modification and extra softening of the blue glass. E. J. V.

Colored glass and glass decoration. JAMES H. GARDINER. *Amer. Glass Rev.*, **45** [33], 17 (1926).—The colored glass problem is in a transition stage. The obvious move is for the production of glasses with definitely stated color values. This is bringing into greater use such instruments as the polariscope, spectroscope, opacitymeter and tintometer. The tintometer and its application are explained, using as an illustration the methods used in a flint glass plant employing a tintometer for a check on their colors. The production of iridescent glass by the action of chlorine gas, or a spray of hydrochloric acid on the surface of lead glassware is discussed. E. J. V.

Preparing steel plates for deep etching. RUDOLF SEDLAK. *Amer. Glass Rev.*, **45** [36], 19 (1926).—Deep etching on glass is most economically produced by printing from a highly polished, engraved steel plate. The plates are thoroughly smoothed, covered with etching resist and the design cut through the resist with an engraving needle. Two formulas are given for etching resist. After the design is engraved the back of the plate is covered with the etching resist and the plate is then placed in a porcelain pan filled with an acid soln. consisting of 1 part nitric acid, 1 part alcohol, $\frac{1}{2}$ part quicksilver, and 5 parts distilled water. When the design is eaten out to the

desired depth, the plate is removed from the acid and the resist washed off, leaving it ready for the printer. E. J. V.

The alleged Holbein stained glass pictures in Augsburg. ANON. *Diamant*, **47** [32], 686–88 (1925).—An enumeration and description of stained glass windows attributed to Hans Holbein which can be found in Augsburg. E. J. V.

The American technique of fire polishing glassware. ANON. *Diamant*, **47** [32], 690 (1925).—A short discussion of methods of fire polishing glassware and its decoration by use of vaporized stannous chloride, as practiced in America. E. J. V.

Antique glasses. ANON. *Diamant*, **47** [33], 715 (1925).—Chem. anal. of antique glasses dating from 1400 B.C. to 600 A.D. show a high alkali content and traces of sulphate which are probably due to the low temp. obtainable in the primitive wood-fired fur. The ancients used only the oxides of copper, lead, manganese, and iron as colorants. Cobalt was unknown, being used for the first time in Venetian glasses in 1443 A.D. Blues were produced with copper oxide, reds by reducing copper oxide, greens with combinations of iron and manganese oxides, purples with manganese, and blacks with copper oxide and a higher manganese oxide. The white incrusted and iridescent glasses were decomposition phenomena produced by the solution of alkalis in the glass in water, leaving a siliceous skeleton. When this process was in the beginning phases there was only a thin layer of silica present which produced the iridescent effect by the dispersion of light rays. E. J. V.

The porcelain painters' special school at the united technical schools at Zwickau. H. WEIDEMAN. *Keramos*, **5** [3], 127–30 (1926).—A description of this special school, giving an outline of courses offered and detailed information regarding some of the courses. E. J. V.

The melting of yellow glass. ERICH FELSNER. *Glass Ind.*, **7** [6], 139–40 (1926).—Of all the varieties of colored glass, yellow is the most difficult to make. Formulas of coloring agents are given. In order to obtain a non-foaming glass the melting must be done very slowly. The cullet should be melted thoroughly and then the glass batch added in small amts., producing a homogeneous mix due to the movement of the glass caused by the foaming in the pot. In this way the loss which would be suffered by glass foaming over when a large batch is melted is avoided. E. J. V.

Colorimetry. J. GUILD. *Trans. Optical Soc.*, **27,** 106–58 (1926); *Chem. and Ind.*, **45B,** 303 (1926).—Three papers: (*a*) Criticism of the monochromatic-plus-white method of colorimetry; (*b*) A new method of colorimetry; (*c*) A trichromatic colorimeter suitable for standardization work. Monochromatic color standards are produced spectroscopically. H. H. S.

Pottery from the ancient "oppidum" of Vindalium (Vaucluse). L. DESVERGNES. *Ann. Chim. Anal.*, **8,** 40–41 (1926); *Chem. and Ind.*, **45 B,** 323 (1926).—Two types of pottery found on Mt. Sève on the site of Vindalium had the following characteristics: (1) Soft and fine, fracture ash-colored and homogeneous, density 1.718, loss at red heat 21.26%, compn. SiO_2 50.07, Al_2O_3 16.92, Fe_2O_3 6.46, CaO 5.13, MgO 0.13%; (2) Hard and coarse, yellow periphery and dark brown center, density 1.885, loss at red heat 8.31%, compn. SiO_2 70.65, Al_2O_3 8.55, Fe_2O_3 9.49, CaO 2.79, MgO 0.21%. H. H. S.

Cement, Lime, and Plaster

Coloration of cement. G. N. WHITE. *Chem. Age*, **14,** 435 (1926).—The use of a dyestuff of organic nature which on exposure to air or simple treatment to bring about oxidation ppts. out of soln. and is coagulated on the surface of the cement particles. 0.1–0.6% gives sufficient amt. to color the mass. The concrete of 7 : 1 ratio has the same depth of color using 0.06% as neat cement using 0.4%. The coloring is thus a

case of surface area covered and not inclusion. The organic matter is resistant to H_2S and SO_2 attack. S. S. C.

Aluminous cement. H. EISENBECK. *Chem. Ztg.*, **50,** 165–67, 202–204, 239–40, 245–48 (1926); *Chem. and Ind.*, **45B,** 408 (1926).—Hardening of aluminous cement is accompanied by a considerable rise in temp., which enables the cement to be used in cold weather with the minimum of protection. Aluminous cement offers much greater resist. than Port. cement to attack by water contg. alkali, acid, sulphates, or Mg salts, and is therefore very valuable in sea-water work. The price of the cement is double that of Port., but a much leaner mix can be used, and the rapid hardening properties permit of economy in time and in initial outlay on forms, shuttering, and the like. H. H. S.

Hydraulic cement from copper slag. G. AGDE AND P. ASSMANN. *Z. angew. Chem.*, **39,** 271–76 (1926); *Chem. and Ind.*, **45 B,** 408 (1926).—A slag from the recovery of Cu from alloys with base metals, contg. 42 % SiO_2, 13.2 % FeO, 1.7 % Fe_2O_3, 23.5 % CaO, was used for cement by an ordinary oxidizing burning with addition of lime. Presence of CuO and Cu_2O is not detrimental. The strength is greatly diminished by more than 0.6 % P_2O_5. Addition of 3 % gypsum accelerates final setting. H. H. S.

The three-component system CaO-SiO_2-Al_2O_3 as hydraulic binding material. R. GRÜN. *Zentr. Bauverwalt.*, **46** (1926); *Chem. and Ind.*, **45 B,** 323 (1926).—No hydraulic binding mats. are known which do not contain lime. Cementitious mats. consist essentially of CaO, SiO_2, and Al_2O_3, and their hydraulic properties depend on their CaO content as represented by Ca aluminates and silicates. The aluminates, which harden very quickly, are the important constituents of alcements and high aluminous slags, while the silicates determine the slower setting of Port. cement and blast fur. cement. H. H. S.

Thermal investigation of blast furnace slags. R. GRÜN. *Mitt. Forschungsinst. Hüttenzement Ind.*, 1925; *Chem. and Ind.*, **45 B,** 324 (1926).—Heat of hydration of a slag bears no direct relationship to its hydraulic properties. The heats of soln. and hydration depend on the $3CaO.SiO_2$ present, while fluxes and $2CaO.SiO_2$ govern setting and hydraulic properties. But the phys. nature of the slag may be studied more accurately by heat of soln. than by microscopic examn., as the energy content measures the extent of vitrification. H. H. S.

Use of newly made hot cement. R. GRÜN AND W. MUTH. *Baumarkt, Leipzig*, (1925); *Chem. and Ind.*, **45 B,** 324 (1926).—The view generally held that new hot cement is dangerous from the strength standpoint is disproved for blast furnace cement. H. H. S.

Modern Portland cement manufacture. S. DICKSON. *Chem. and Ind.*, **45,** 346 (1926).—The greatest improvement in recent years has been in the fine grinding of raw mats. There are now many Port. cements which compare favorably with alumina cements for quick setting and strength. The new cements have a 7-day strength of 700 lbs., as compared to 390–450 lbs. of the ordinary, less finely-ground, cement of the same compn. The chief development in machinery is a combination mill into which clinker and gypsum are delivered automatically in suitable proportions. The grinding is graduated, the crushed mat. passing from section to section, the final grinding being extremely fine. An elutriator for sepn. of coarse particles is regarded as better than air separation. H. H. S

Modern Portland cement manufacture. R. H. H. STANGER. *Chem. and Ind.*, **45,** 346 (1926).—Developments since the introduction of the first stand. specification in

1905 are dealt with. The sand specification of a 20-mesh sieve should be graded to 30. Last year the permissible MgO content was raised from 3 to 4%. A compression test has been adopted in every country except Gr. Britain and the U. S., and the author thinks that it will have to come. In the discussion, G. Martin contended that there had been no economy in fuel per 100 T. cement during the last 20 years, and recalled the promises made of fuel reduction when rotary kilns were introduced. W. Reid said that in his experience the whole cement industry had developed through the application of chemistry. H. H. S.

Pyro- and hydro-treatment of magnesite and dolomite. H. M. HENTON. *Trans. Am. Inst. Mining Met. Eng.*, Feb., **1926,** No. 1573-H, 34 pp.—The increasing use of "plastic magnesia" requires larger quantities of MgO. Previous results have stimulated invest. as to the available raw mats. Six means of sepg. CaO from MgO in dolomite and magnesian limestones are listed. Any process must combine cheapness in calcination, in conversion of MgO to a sol. form, in effecting soln. and a satisfactory filtration from lime and sepn. of MgO from the soln. A lab. investg. and app. and later field equipment are described and exptl. data are tabulated. Uses of products and by-products are listed and exptl. results are discussed under 3 heads: proper and cheap calcination of dolomite; commercially feasible carbonation, bicarbonation and soln. of MgO; practical sepn. from CaO and pptn. of the $Mg(HCO_3)_2$. A plan of an exptl. plant, a suggested flow sheet for a MgO sepn. process, and a possible CaO disposal are shown. Nine favorable conclusions are listed and a very complete bibliography is appended. (*C. A.*)

PATENT

Manufacturing process for cements containing iron and alumina combinations. ERNEST MARTIN. U. S. 1,586,099, May 25, 1926. A process of producing cements containing iron and aluminum combinations possessing hydraulic binding qualities, which consists in forming a mixt. of raw mats. containing $CaCO_3$, Fe_2O_3 and Al_2O_3 in the proportions of more than 2 mols. of $CaCO_3$ for each mol. of Fe_2O_3 and one mol. of $CaCO_3$ for each mol. of Al_2O_3, and firing said mixt. at a temp. below the m. p. of any of the ingredients.

Enamels

The "refractory value" of enamels.—A discussion. *Ceramist*, **8** [1], 38–50 (1926).—*Refractory Value* (abstract from Staley's article *Ceramist*, **6** [1]). Refractoriness must depend largely on the compn. Detn. of the "refractory value" of ground coats is an attempt to calculate the relative refractoriness of ground coat enamels from their melted compns. by assigning certain factors to the various constituents. S. gives the factors and shows how the refrac. value is obtained by dividing the "units of refractoriness" by the "units of fusibility." In working with a wide variety of ground coats, it has been found that the refrac. value of those used for sanitary ware was about 2.80, or that the ground could be improved by bringing the value to that figure. The refrac. value of a ground to be used in a certain class of work depends more upon the temp. of the fur. than on the class of work. *M. E. Manson.* M. questions the assignment of the value 3 to Al_2O_3, with SiO_2 as 1, because according to "flint equivalent" calcns. alumina has only 1½ times the effect of SiO_2. M. also questions the choice of 2.8 as the ideal refrac. value. In his own fur., operg. at about 1800°F, a ground coat with a R.V. of 4.2 was superior to one with a R.V. of 2.8. *Arthur P. Woolfolk.* W. finds no discrepancies in applying Staley's method to his ground coat. *Robert C. Boyd.* The best R.V. for a ground coat will depend on the temp. at which the enamel is fired. At low temp. (1450°F.) a R.V. of 2.2 gives good satisfaction. B. gives reasons for believing that the

R.V. could be higher if the percentage of raw additions were lower. *A. Malinovzsky.* M. (like Manson) questions the assignment of the value 3 to Al_2O_3 and states that he has used the value 1.7 for years with good results. A groundcoat of R.V. 2.76 has given good results. On mixing Staley's ground coat No. 4 (R.V. 2.81) it was found to work excellently in the range 1600–1700°F. *H. F. Staley.* The factors 10 and 15 used in calculating the flint equivalent give no indications of the relative effect of silica and alumina resp. on refractoriness. One part of alumina increases the refractoriness 3 times as much as one part of silica. S. shows how the factors 10 and 15 provide a simple empirical formula and do not contradict the above statement. The refrac. value to be set up in a given plant will depend on the temp. at which the furs. are operated as well as the percentage of raw additions. A. E. R. W.

Melting cast iron in electric furnace. E. RICHARDS. *Stahl u. Eisen*, **46,** 249–54 (1926); *Chem. and Ind.*, **45 B,** 324 (1926).—Elec. fur. cast iron has better mech. properties, is denser, and has a finer-grained fracture than cupola iron, and the foundry is independent of the coke supply. But as the elec. process is expensive, the "Duplex" process, in which the cupola is used in conjunction with a basic-lined electric fur., is recommended. Oxygen is removed by both the Mn and the C; CaC_2 is formed near the electrodes, and S is removed by the combined action of CaO, C, and CaC_2.

H. H. S.

A3 and A4 transformation of iron. S. SATO. *Sci. Rept. Tohoku*, **14,** 513–27 (1925); *Chem. and Ind.*, **45 B,** 324–25 (1926).—In pure iron, during heating, the A4 transformation is accompanied by an expansion, and the A3 by a contraction. These changes are reversed in cooling, the ratio of magnitudes of change in length being A4 : A3 : : 10 : 3.

H. H. S.

Solidus lime in iron-carbon system. S. KAYA. *Sci. Rept. Tohoku*, **14,** 529–36 (1925); *Chem. and Ind.*, **45B,** 325 (1926).—The solidus lime, detd. by elec. resist., of Swedish steels ranging from 1.60 % C (solidus pt. 1140°) to 0.23 % C (solidus pt. 1444°), lay between the curve obtained by Carpenter and Keeling, and that of Gutowsky. The soly. limit of cementite was 1.7 % C.

H. H. S.

Heat of precipitation of cementite from martensite. M. KAWAKAMI. *Sci. Rep. Tohoku.*, **14,** 325 (1926).—Heat of pptn. increases proportionally to C content. For eutectoid steel it is 3.7 cal. per gm. from α-martensite, and twice as much from β-martensite. H. H. S.

BOOKS

HERTWIG-MÖHRENBACH: **Der Emailliermeister. Das Emaillieren.** Dresden: "Die Glashütte." 176 pp. R. M. 5. (*C. A.*)

RANDAU, PAUL: **Die Fabrikation des Emails und das Emaillieren.** Vienna: A. Hartleben. 210 pp. R. M. 4. (*C. A.*)

PATENT

Apparatus for coating with glass or enamel. ELI K. HOUGHTON. U. S. 1,585,990, May 25, 1926. An app. for applying coatings which consists of a pair of flexible conduits, nozzles mounted on the ends of the conduits, means for fastening the nozzles together in such a manner that the streams discharged therefrom intersect, valves mounted upon the nozzles, a fuel supply to which one of said flexible conduits is connected, a container containing a fusible comminuted mat. to which the other flexible conduit is connected, a conduit extending into said container for supplying compressed air thereto, and a valve upon the last mentioned conduit controlling the supply of compressed air to the container.

Glass

A new glass stone: $Na_2O \cdot 3CaO \cdot 6SiO_2$. ALBERT B. PECK. *Jour. Amer. Ceram. Soc.*, **9** [6], 351–53 (1926).—Attention is called to a stone of different compn. than any heretofore recorded, and but recently possible of identification by petrographic-microscopic means through the work by Bowen and Morey on the system Na_2SiO_3–$CaSiO_3$–SiO_2. Various ways by which attempts were made to determine the compn. of the crystals are described and a summary of the optical properties of these crystals from three sources is given. Probable places for the formation of these stones in the tank are also indicated.

Depression in Czechoslovak hollow glass industry. ANON. *Amer. Glass Rev.*, **45** [33], 15 (1926).—Due to a decline in the export trade and slack domestic demand, the hollow glass industry in Czechoslovakia is passing through a period of depression. Additional aggravating factors are increase in price of sulphates, which has caused the Glass Manufacturers Assn. to petition for a reduction in import duty. Many skilled workers are moving to France as a result of the depressed condition. E. J. V.

Glass annealing process is discussed in technical bulletin. ANON. *Amer. Glass Rev.*, **45** [33], 16 (1926).—A brief résumé of Tech. News Bull. 108 of the Bur. Stand. on "Annealing of Glass." Annealing is the process of removing strains from glass by holding it at some temp. in the annealing range long enough to permit stresses to disappear and then cool so slowly they do not develop again. Compn. of the glass governs the annealing range. The safe cooling rate is governed by the thickness of the glass. The degree of annealing or amt. of strain is generally detd. by examining the glass in a beam of polarized light. E. J. V.

Glass Container Association meeting in Montreal most successful. ANON. *Amer. Glass Rev.*, **45**, [34], 15 (1926); *Nat. Glass Budget*, **42** [4], 3 (1926).—A report of the meeting in detail with President Ferguson's address included in full. E. J. V.

Facts should govern glass container industry. W. H. BOSHART. *Amer. Glass Rev.*, **45** [35], 17 (1926); *Nat. Glass Budget*, **42** [4], 3 (1926); *Glass Industry*, **7** [6], 144–45 (1926). —B. tells manufacturers that excess producing capacity may be harmful. He urges attention to facts and wants wider use for glass containers. E. J. V.

Glass and silica in LaSalle county. J. J. KELLY. *Amer. Glass Rev.*, **45** [35], 19–23 (1926).—Over 50% of the window glass manuf. in the United States is purchased within a radius of less than 400 miles from LaSalle County, Illinois. The highest grade silica sand is mined in large quantities in this county. K. traces a brief history of glass manuf. and also shows how important a part products from LaSalle county play in our every-day civilization. E. J. V.

Silica investigation. ANON. *Amer. Glass Rev.*, **45** [36], 27 (1926).—A note on an investg. of silica in all its various phases carried on by the Bureau of Mines, Washington. A bulletin giving results is to be published. E. J. V.

Glass as an architectural building material. BRUNO TAUT. *Diamant*, **47** [33], 711 (1925).—Up to the 19th century glass was used only for windows in bldg. With the erection of the Crystal Palace in London, its use as a bldg. mat. was begun. Modern methods of employing glass in bldg. are discussed. E. J. V.

The valuation of opacifying materials. ANON. *Glass Ind.*, **7** [5], 114 (1926).—A discussion of fluorspar and cryolite as opacifying agents. Methods of anal. of each mat., with special emphasis on detn. of fluorine and iron, are outlined, E. J. V.

Glass wool as insulator for refrigerators. H. C. BATES. *Glass Ind.*, **7** [5], 117 (1926). —A short discussion of the properties of glass wool and results of an invest. comparing the thermal condy. of it with other mats. used as insulators for refrigeration purposes are given. E. J. V.

The frosting of glass. FRIEDRICH SPATE. *Glass Ind.*, **7** [6], 131–35 (1926).—Different methods of roughening a smooth glass surface are discussed. These include: (1) chem. with hydrofluoric acid; (2) mech. with sand blast; (3) by the combination of chem. and sand blast method; (4) by the action of glue on glass frosted chemico-mechanically. The roughened surface disperses light but even the most intensive frosting did not reach opal glass in the light dispersion effect expts. have shown. E. J. V.

New glass transmits ultra-violet rays. FRED M. LOCKE. *Glass Ind.*, **7** [6], 136 (1926).—A glass equal to fused quartz in the transmission of ultra violet rays has been patented by the Fred M. Locke Research Laboratory. It is equal to optical glass in clearness and translucency, has a low expansion comparable to chem. glass, insulates electricity up to the m.p. of the glass itself, can be melted in the ordinary tank or pot, and is only slightly higher in cost than ordinary plate or window glass. In its simpler form it contains only four ingredients: silica, hydrated alumina, boric acid, and fluorspar, being essentially free from alkalis. It is highly stable against the attack of steam, water, acids, and atmospheric conditions and fairly stable against the action of alkalis. E. J. V.

Valuation of aluminum bearing materials. ANON. *Glass Ind.*, **7** [6], 140–41 (1926). —Methods of anal. of the mat. used in glass making as sources of aluminum are outlined. E. J. V.

Sandless glass. ANON. *Glass Ind.*, **7** [6], 143 (1926).—The production of glass employing germanium oxide as a substitute for silica sand, by Professor Dennis of Cornell, is mentioned. E. J. V.

The manufacture and use of actinic glass discussed. ANON. *Nat. Glass Budget*, **42** [5], 3 (1926).—Actinic glass absorbs heat rays, transmits luminous rays and reduces glare. The glass is a result of work done by Sir William Crookes, who found that by use of certain salts these properties were given to a glass. It is produced commercially by the Pennsylvania Wire Glass Co. at Dunbar, Pa. Properties and uses of different forms of actinic glass products are enumerated. E. J. V.

Liquid filters of glass. ANON. *Nat. Glass Budget*, **42** [5], 21 (1926).—Filter plates made of pulverized Jena glass lightly fused together are produced by the Jena Glass Works. E. J. V.

How vitrolite is manufactured. ANON. *Ceram. Ind.*, **6** [6], 587–90 (1926).—Vitrolite is a glass used for table tops, shelves and similar articles. The melted glass is brought from a continuous tank and poured onto a table, where it is rolled into about $\frac{7}{16}$-inch sheets. If thicker sheets are desired, they are built up by pouring more melted mat. over the already formed sheets, while they are still hot. The sheets are then carefully annealed, polished and cut to size. R. E. G.

Reconstruction of the power installation of a glass factory. ANON. *Archiv für Warmewirtschaft*, **7** [5], 144–46 (1926).—Description of power installation for a glass factory in which melting tanks are heated by regenerators, and outline of revised construction in which cooling heat is utilized to operate a turbine. Calcns. of heat economy show that the saving may cover the cost of the installation in from 15 months to 2 years. E. E. P.

The development of modern laboratory glassware. W. E. S. TURNER. *Chem. Age*, **14**, 398–99 (1926).—Prior to 1870, much lab. app. in England was made of potash-lead-oxide glass. Shortly after 1870, German soda glass was introduced and also Kavalier's glass of compn.: SiO_2–75.8%, CaO–8.6%, Na_2O–6.9%, K_2O–7.9%. Jena glass was brought out in 1892. In America, a copy of Kavalier's glass was introduced in 1898, and Nonsol in 1903. The world war stimulated the development of chem.

glassware. Pyrex glass was developed in America by the Corning Glass Co. through long researches begun before the war, and is now produced under license by other manufacturers including a firm in England and one in France. The development of the British glass mfg. industry in the last 10 years is considered very satisfactory.

E. E. P.

Glass: Physical properties in relation to chemical composition. W. E. S. TURNER. *Chem. and Ind.*, **45,** 332 (1926).—Knowledge of the particular chem. compds. that are present in glass is still very elementary. Although it has been suggested that the oxides in glass are in a state of dissociation, the compds. being definitely established only by their sepn. as crystals, a large number of simple and complex silicates have been isolated and characterized from fusions contg. the oxides used in glass-making. X-ray examn., however, reveals but little indication of structure. Certain similarities in the behavior of glasses and zeolites suggest that the latter are probably glasses which by weathering have been modified so as to render their constituents easily capable of extraction or substitution. The author discusses the nature of problems which are essentially chem. in character, *e.g.*, light absorption, color, viscosity, resistance to water and to reagents, and finally the influence on the properties of glass of concn. and specific compn.

H. H. S.

Transparent silica glass. H. GEORGE. *Compt. Rend.*, **182,** 850–51 (1926); *Chem. and Ind.*, **45 B,** 360 (1926).—Transparent silica, free from gas bubbles, is obtained by fusion of certain very pure natural quartzites which are built up of microscopic crystals of SiO_2 and contain no occluded gases. This quartz does not crack or disrupt on heating to fusion.

H. H. S.

Light-dispersion glasses. G. SCHOTT. *Glastechn. Berichte,* **3,** 315–29 (1925); *Chem. and Ind.*, **45 B,** 407 (1926).—The two chief types are: (1) transparent glasses with specially treated surface, such as holophane, which has parallel ribbing on the inner surface, and sandblasted and etched ware; (2) glasses, inhomogeneous throughout, *e.g.* alabaster, opal and milk glasses. Alabaster glass is formed by devitrification, using a potash-lime silicate of low lime content. Opal effects are obtained from SnO_2, ZrO_2, TiO_2, F compds., or by phosphates. The 3 causes of light-scattering are refraction, reflection, and diffraction, all of which may be operative at the same time. When the size of particles is of the order of a wave-length of visible light, diffraction becomes the most important factor. The % light loss on transmission through various glasses is: clear glass 5.5, etched 7.5, sandblasted 11.2, casing 9.3, 11.5, 27.0, according to thickness, Jena milk 19.5, Peters 25.2. The efficiency of a dispersive glass is: E = scattering power absorption.

H. H. S.

Nomenclature and classification of optical glasses. P. NICOLARDOT. *Rev. Gén. Colloid.*, **4,** 9–13, 39–50 (1926); *Chem. and Ind.*, **45 B,** 407 (1926).—Classifications suggested by Zschimmer, Zschokke, Morey, Peddle, and Montgomery are examined. The schematic diagram of Montgomery, modified by plotting log (dispersive power) against index of refraction, is adopted. Since the region richest in glasses then becomes cramped, a division into diagrams is proposed, corresponding to visual, photovisual, and photographic:

Visual: $x = n_D$, $y = \log V_D$, $V_D = \dfrac{n_F - n_C}{n_D - 1}$

Photovisual: $x = n_F$, $y = \log V_F$, $V_F = \dfrac{n_G - n_D}{n_F - 1}$

Photographic: $x = n_G$, $y = \log V_G$, $V_G = \dfrac{n_H - n_F}{n_G - 1}$

H. H. S.

The hardness of glasses. A. LECRENIER. *Keram. Rundschau*, **33**, 205–6; *Chem. Zentr.*, **1925**, I, 2463.—With the same SiO_2 content soda glasses are in general harder than potash glasses. With pure soda lime glasses, the hardness for a given SiO_2 content increases with an increase in potash and decrease in soda. B_2O_3 also increases the hardness. Soda and potash increase the hardness of Pb glasses. (*C. A.*)

Glass that bends is made from urea. ANON. *Oil, Paint & Drug. Rept.*, **109**, No. 9, 21 (1926).—A formaldehyde condensation product with urea, called "pollopas," made by Fritz Pollak of Vienna, has many of the properties of glass, but is not brittle. It is transparent to visible and ultra-violet light. Its d. is only about 25% that of flint glass, and it has good mech. strength. Suggested uses are for windshields, railway car windows, novelties, etc. (*C. A.*)

Jena sintered glass crucibles. G. D. ELSDON. *Analyst*, **51**, 30–31 (1926).—For weighing the Cu_2O in sugar detns. the most suitable size is 1 b G 3/<7. Hot alkali acts slightly upon the crucible. (*C. A.*)

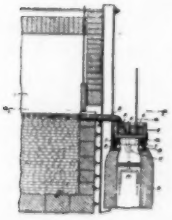
BOOKS

Die Glasfabrikation. ROBERT DRALLE. Vol. 1. General. Second edition, completely revised. Edited by Dr. Gustave Keppeler. 778 pages, 714 illustrations, 16 tables. R. Oldenbourg, Munchen. Paper, $15.00; Cloth, $16.00. Contents: Chap. 1. Phys. and chem. foundation of glass manuf., G. Keppeler; 2. The raw mats. and their prepn., G. Keppeler and Muhlert; 3. Process of melting, refining and cooling, G. Keppeler; 4. Fuels, G. Keppeler; 5. Design and opern. of gas producers, O. Wolff; 6. Supervision of fur. operns.; H. Maurach; 7. Refracs., G. Keppeler; 8. Furnaces, O. Wolff and G. Keppeler; 9. Glassworking machinery, A. Wendler. This generally and internationally recognized leading scientific work on the glass industry needs no special announcement. The second vol. will take up the individual branches of the glass industry and will appear in the fall of 1926. E. J. V.

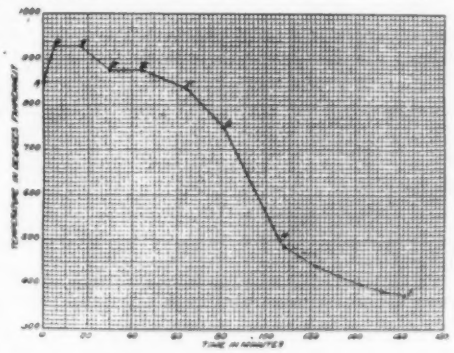
Text book of glass technology. F. W. HODKIN AND A. COUSEN. Pp. 574. London: Constable & Co., 1925. Price 42 *s.* H. H. S.

PATENTS

Manufacture of sheet glass. C. H. HARDING. U. S. 1,584,768, May 18, 1926. The method of manuf. of sheet glass which comprises developing the sheet from a body of molten glass and during the opern. shifting the line of sheet-development in its own direction.

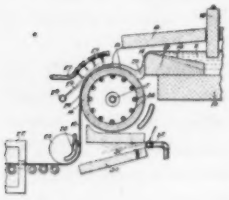


Process of annealing glass. K. M. HENRY. U. S. 1,585,542, May 18, 1926. In a process of annealing glass articles in a temperature-controlled leer or muffle, the steps of subjecting the glass-ware to a plurality of annealing stages, first at a high temp. and thereafter at a lower temp., all within the annealing range.



Method of and apparatus for handling glass. C. W. KURTZ, O. M. BYERS, L. R. SCHMERTZ, AND L. A. GESSNER. U. S. 1,586,091, May 25, 1926. In a glass handling app., an interrupted glass-carrying means, a leer through which one section of said means passes, a htg.

chamber through which another section of said means passes, and means between the leer and htg. chamber for dipping the glass carried by said means.

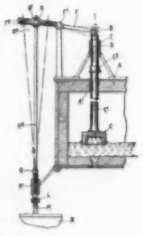


Method and apparatus for producing sheet glass. E. T. FERNGREN. U. S. 1,586,187, May 25, 1926. In sheet glass app. a fur. containing a mass of molten glass, a rotatable drum, means for permitting a flow of glass to pass from the fur. upon the drum in a manner that it will tend to move on the drum in a direction opposite to its rotation, and means for drawing a sheet from the glass on said drum, the sheet being drawn in the same direction as that of rotation of the said drum.

Method and apparatus for drawing sheet glass. E. T. FERNGREN. U. S. 1,586,618, June 1, 1926. In the art of drawing sheet glass from a mass of molten glass, the method of maintaining lateral tension in the sheet during the formative period, consisting in forming thickened edge portions on the sheet at the sheet source, gripping the thickened portions between rolling surfaces after they have passed beyond their place of formation and immediately adjacent thereto and holding the sheet against its tendency to contract.

Method and apparatus for supplying molten glass to sheet-drawing machines. E. T. FERNGREN. U. S. 1,586,619, June 1, 1926. In an app. for drawing sheet glass, wherein the sheet is drawn upwardly from a rather deep pool of molten glass, means for segregating a shallow body of the molten glass below and adjacent the sheet source, comprising a submerged refrac. plate with its upper surface substantially parallel with the surface of the pool, the plate having a substantially flat upper surface but being thicker at the center than adjacent the sides of the pool, for the purpose described, and htg. chambers contained within the ends of the plate.

Method and apparatus for continuously drawing sheet glass. E. T. FERNGREN. U. S. 1,586,620, June 1, 1926. The method of producing sheet glass, wherein a layer of cooler plastic glass is congealed upon a portion of the surface of a pool of liquid glass this layer being reheated and then floated over the edge of the containing receptacle upon a film of liquid glass and drawn away in sheet form.



Apparatus for controlling the delivery of glass from furnaces to molds and the like. J. D. ROOTS. U. S. 1,586,704, June 1, 1926. An app. of the character described including a receptacle for containing molten glass, said receptacle having a discharge opening therein, a plunger mounted to reciprocate relative to the receptacle and for controlling the discharge of glass through the opening, said plunger including a hollow stem and an enlarged recessed head, the hollow stem allowing the exhaust of air from the head whereby glass may be received in the recess of the head at all times, and means for raising and lowering the plunger, said plunger when being raised creating a vacuum to raise the glass and cut off discharge thereof through the opening and when being lowered discharging the glass through the opening.

Automatic glass-blowing machine. C. A. BROWN AND A. C. NIELSEN. U. S. 1,587,466, June 1, 1926. In an automatic mach. for making glass articles, the combination of a substantially horizontally disposed carrier, a substantially vertically disposed guide attached to said carrier, a head supported independently of said carrier and slidably mounted on said guide and comprising means for receiving and retailing the end of a glass tube, means positioned to engage another portion of said tube and adapted to center it without supporting it, htg. means adapted and arranged to be brought into operative relation to the free end of said tube, molding means adapted and arranged

to engage said tube and mech. whereby said htg. and molding means are caused to operate in proper sequence.

Feeding mold charges of molten glass. K. E. PEILER. U. S. 1,587,985, June 8, 1926. The method of forming a mold charge of molten glass from a flowing stream, which consists in winding the stream upon itself to form a gather, pulling the gather away and sepg. it from the stream, stopping the winding action and suspending the gather, and severing a mold charge from the suspended gather.

Multiple glass feeder. K. E. PEILER. U. S. 1,587,986, June 8, 1926. The method of obtaining gathers of molten glass from a supply, which consists in winding the glass in succession upon a plurality of rotating gathering implements, and increasing the distance between the implements to pull their respective gathers apart.

Glass-feeding apparatus. T. C. STEIMER. U. S. 1,588,393, June 8, 1926. The method of delivering glass from a source of supply through a spout, which comprises flowing a temp. modifying medium around and in contact with the walls of said spout, and then delivering such fluid into the spout interior above the glass line.

Feeding molten glass. K. E. PEILER. U. S. 1,589,304, June 15, 1926. Glass gathering app., comprising a receptacle for molten glass, means for delivering formed lumps of viscous glass therefrom, and knives for severing each lump as formed, said knives being adjustable along the path of delivery of such lumps.

Apparatus for annealing glassware. K. E. PEILER. U. S. 1,588,905, June 15, 1926. App. for annealing glassware comprising a tunnel section having a metallic wall and a flue formed integrally with said wall. App. for annealing glassware, including a tunnel comprising a plurality of self-supporting metallic sections arranged in end-to-end relation, each of said sections having a passageway for ware and a passageway for a temp.-controlling medium, said passageways being sepd. by a wall common to both of said passageways.

Method of making mold-blown glass articles. THOMAS A. NILAN. U. S. 1,588,852, June 15, 1926. The method of making mold-blown glass articles which includes providing a mold-blown glass article with an opening other than the blow opening, and specially applying heat to the portions of the article adjacent the opening, substantially as described.

Apparatus for annealing glassware. VERGIL MULHOLLAND. U. S. 1,588,603, June 15, 1926. App. for annealing glassware comprising a tunnel, a plurality of flues associated with said tunnel, a fire box communicating with one of said flues at a point adjacent to the entrance end of said tunnel, a fire box communicating with another of said flues at a point remote from the entrance end of said tunnel, and means for causing heated gases to flow through the portions of said flues located between said fire boxes in opposite directions with respect to each other.

Removal of glass from glass furnaces. HEINRICH SEVERIN. U. S. 1,589,337, June 15, 1926. A method of withdrawing glass directly from a glass fur. having definite dipping chambers and clarifying rings for the mold, consisting in this that the mold is inserted into the molten glass at the dipping chamber and the glass adhering to the mold, when the latter is withdrawn, is cut off and thrown into the clarifying rings externally of the dipping chamber, as and for the purpose set forth.

Heavy Clay Products

A modern sewer pipe plant. W. D. RICHARDSON. *Jour. Amer. Ceram. Soc.*, 9 [6], 354–61 (1926).—A sewer pipe plant design including radical departures from plants in operation now is described. Tunnel driers of special design are suggested as most practical. Salt glazing in continuous kilns, using gas or oil as fuel, is discussed. A feeder for introducing the salt into the kiln is described.

E-90-P comparative test of hammer mill pulverizer and dry pan for crushing Streator shale. D. P. OGDEN. *Jour. Amer. Ceram. Soc.*, **9** [6], 362–69 (1926).—In the machs. as described below the following points are discussed: (1) the grinding action, (2) energy consumption per ton ground, (3) capacity to produce fines six-mesh and under, (4) to determine the operg. characteristics of the hammer mill. The conclusions given are: (1) The dry pan will not grind shale chunks larger than 15 in. max. diameter, nor chert nodules of any size. The hammer mill grinds easily in one opern. all chunks small enough to go through the 20 x 42-inch hopper opening and all chert nodules. (2) The energy consumption of the dry pan as compared to the hammer mill in kw. hrs. per ton of fines through six-mesh is approx. as 1.40 to 1.25. (3) The max. capacity of the Frost 9-foot dry pan with $\frac{1}{4}$-inch screen plate openings was known to be approx. 25 tons through six-mesh per hr. The max. capacity of the 30 x 42-inch Williams hammer mill as reached in these tests with hand feeding was found to be 56 tons total feed and 42 tons through 6-mesh per hour. This figure could have been greatly exceeded if the mat. could have been fed more rapidly. The dry pan tailings coarser than 6-mesh compared to the hammer mill tailings of the same coarseness are as 40 to 25 %. (4) The hammer mill is more efficient than the dry pan in practically all respects if properly set up and operated, but it is easily possible to secure less efficient results from the hammer mill, particularly if the feeding is not properly regulated.

Sixteen million fine face brick annually, with only nine twenty-seven foot kilns. ANON. *Clay Worker*, **85** [5], 396–99 (1926).—The plant of the Dixie Brick Co., of Columbus, Ga. is described. The plant operates with a very high degree of efficiency, although it has very tender drying properties and a very narrow firing range of 40°F. The clay deposits have been very thoroughly tested every 50 ft., by boring, and the firing behavior of each location noted. The brick are dried in a waste heat drier made by the Minter System, which uses only clean heat. This insures freedom from scumming and also saves the drier equipment. The Minter System is used in the firing. Firing is controlled by pyrometers. R. E. G.

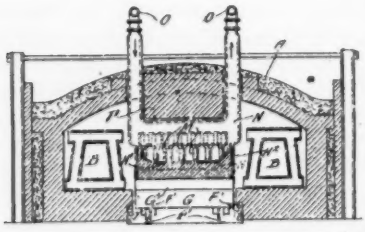
The march of progress in Canada. E. J. WINKLEMAN. *Brick and Clay Rec.*, **68** [11], 867–70 (1926).—A description of the new plant of the Cooksville Shale Brick Co., at Toronto, Ontario, Canada. R. E. G.

Durability of cement drain tile and concrete in alkali soils; fourth progress report (1923). G. M. WILLIAMS AND IRVING FURLONG. Bur. of Standards, *Tech. Paper* No. **307,** 191–240 (1926).—Previous conclusions are confirmed. (*C. A.*)

BOOK

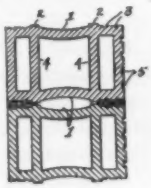
RAULS, FRANZ: **Die Ziegelfabrikation.** Leipzig: Bernh. Friedr. Voigt. 430 pp. M. 25. (*C. A.*)

PATENTS

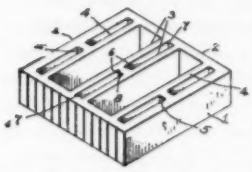


Tunnel kiln. P. A. MEEHAN AND H. M. ROBERTSON. U. S. 1,584,883, May 18, 1926. In a continuous tunnel kiln the combination with the kiln chamber and track rails therein, of means for transporting mat. through the kiln chamber comprising a train of cars each comprising a metallic underframe with track engaging wheels mounted therein and a refrac. superstructure formed with a trough-like cavity in its upper face which extends longitudinally of the car and unites with the corresponding cavities of the other cars to form a continuous trough extending the length of the train.

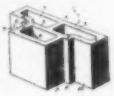
Hollow-clay structural unit. O. C. McCormick. U. S. 1,584,987, May 18, 1926. A structural unit of the character described, comprising a hollow block formed with a longitudinally extending opening and having its top and bottom surfaces provided with centrally located longitudinal grooves, longitudinally extending flat ribs bounding the lateral edges of said grooves, said ribs being raised from said surfaces and adapted to form mortar stops, and two longitudinally extending reinforcing partitions in approx. alignment with said ribs on the top and bottom surfaces of the block providing lateral openings on either side of said longitudinally extending central opening and strengthening said unit adjacent its longitudinal side faces.



Hollow-clay structural unit. O. C. McCormick. U. S. 1,584,988, May 18, 1926. A structural unit of the character described, comprising a rectangular hollow brick equal in its over-all dimensions to 2 standard bricks laid side by side, the opening in said brick extending vertically and said brick having a double transverse partition located mid-way between the ends of such opening and a single partition located adjacent to but spaced from each such end, the side walls of the brick being vertically scored on a line between the parts of said middle partition.



Building block. John Carlsson. U. S. 1,585,374, May 18, 1926. A wall structure formed of a plurality of reversely arranged blocks of substantially T-shaped form and having a head portion and a leg portion, the end faces of the head portion and the sides faces of the leg portion of each block being closely adjacent end faces or side faces of other blocks, the legs of each block being wider at one portion than another whereby cavities are provided in the wall structure between portions of the legs of the blocks and the adjacent surfaces of other blocks, the length of the leg portion of each block being substantially equal to the thickness of the head portion, whereby the inner faces of the head portions of the blocks may overlap and be in substantial contact with portions of resersely arranged blocks throughout the greater part of their length, substantially as decribed.



Clay-cleaning method and machine. C. L. Crabb. U. S. 1,585,771, May 25, 1926. A method of obtaining clean clay from a mass of clay containing foreign particles which consists in shaving from the mass cuttings that are thinner than the largest foreign particle permissible in the clean clay, and simultaneously clearing the cutting edge of the shaving means to prevent clogging thereof.

Process for coloring brick. Adam Sassur. U. S. 1,586,474, May 25, 1926. A shaped plastic article of the character above described containing a cementing agent of a mineral nature, and containing ferruginous quartz in comminuted state as a coloring agent, present to the extent of about 2 to 10%, such shaped article retaining its color when subjected to dry steam treatment for hardening the said article.

Brick carrier. H. K. Schondelmayer, and S. C. Fulkerson. U. S. 1,586,475, May 25, 1926. In a device of the type described, a frame comprising a pair of telescopically arranged tubular members, means for maintaining said members in adjusted relation in respect to each other, a gripping member rigidly carried by one of the frame members, a second gripping member pivotally carried by the remaining frame member, a handle carried by the pivoted gripping member, means for releasably holding the pivoted gripping member immovable in respect to the rigid gripping member and length adjusting means for said holding means whereby the same is adapted to correspond for operative positioning at different adjustments of the tubular members.

Clay tempering and expressing apparatus. W. L. HANLEY, JR. U. S. 1,587,300, June 1, 1926. A mach. of the character described, comprising among its members, a horizontal clay tempering cylinder, and a horizontal clay expressing cylinder, arranged side by side in substantially the same horizontal plane, the discharge end of the clay tempering cylinder being connected to the inlet end of the clay expressing cylinder, by a substantially horizontal throat, clay feeding devices in said respective cylinders for feeding the clay in opposite directions therein, and transferring mech. located in said throat for positively transferring the clay therethrough from the tempering cylinder to the expressing cylinder.

Clay-cutting apparatus. A. V. A. FITZ. U. S. 1,588,018, June 8, 1926. App. for cutting a moving clay body, including a carriage movable from a normal position with the clay to be cut, means for holding the carriage in such normal position, means operated in accordance with the movement of the clay for releasing the carriage to permit travel with the clay, a cutter mounted on the carriage, means for automatically operating the cutter during the movement of the carriage, and means for automatically returning the carriage to its normal position after the cutter has operated.

Refractories

Comparative tests of some American and German fireclay brick. R. F. GELLER AND W. L. PENDERGAST. *Jour. Amer. Ceram. Soc.*, 9 [6], 370–73 (1926).—The Bur. Stand. has recently completed a short investg. comprising comparative tests of 5 brands of German-made brick and 6 brands of American-made brick. The results indicate that the German-made brick are practically the equal of the Amer. brick.

The role of specific heat in the selection of refractories. A. ERNEST MACGEE. *Jour. Amer. Ceram. Soc.*, 9 [6], 374–79 (1926).—A brief discussion of specific heats is given in which particular emphasis is placed upon its detn., the methods which have been used in the past for its detn. at high temps., and the application of the values in the selection of refractories. The need of detg. phys. properties of brick which have been in service is pointed out.

Desirable properties in furnace sand. W. M. WEIGEL. *Can. Chem. Met.*, **10** [5], 104 (1926).—Fur. sand is used to line fur. bottoms and walls and is usually called "silica sand" due to the fact that high silica content, usually 95 %, is specified. A small amt. of bonding mat. is required to hold the sand until it has been "burned in." Alkalis should be at a minimum, while clay is the least objectionable impurity. Small amts. of iron oxide may be present. E. J. V.

The electrical resistance of refractory materials. JOHN B. FERGUSON. *Can. Chem. Met.*, **10** [6], 131–36 (1926).—Commercial refrac. being in general cryst. aggregates cemented together in some cases by a glassy bond, their elec. properties are those of a mech. mixt. of these two types of mat. These two types of mat. are discussed first and followed by a consideration of actual commercial refrac. The relation between elec. resist. and temp. can, according to Rasch and Hinrichson, be satisfactorily expressed by an equation similar to that of van't Hoff. It may be written: $\log \rho = \frac{A}{T} + B$, where ρ is the resistivity, T the temp. abs. scale, and A and B const. peculiar to the mat. in question. If this law is obeyed, a straight line should be obtained by plotting $\log \rho$ against $\frac{1}{T}$. Results obtained by other investigators are discussed and replotted according to the equation given. This includes mats. such as solid glasses, molten glasses, solid and molten glass (through the melting interval), crystals, commercial mat. such as porcelain, pure refrac. mat. including talc, periclase, sillimanite, kaolin, flint fire clay,

silica and diaspore, and actual commercial refrac. as fire brick, silica brick, magnesia brick, chrome brick, alundum, and carborundum. The manner in which the results obtained are in accord or disaccord with the equation is discussed in each case.
E. J. V.

The use of sillimanite in glass works practice. W. E. S. TURNER. *Glass Ind.*, **7** [5], 113 (1926).—Sillimanite refracs. stand up much better in glass works than ordinary fire-clay refracs. They show substantial shrinkages between 1400–1500° C but otherwise have been very successfully used wherever applied. In slip or paste form, its use in stacks of regenerators, leading gas and air to ports has greatly decreased the loss of the brick due to corrosion. E. J. V.

French bauxite. ANON. *Chem. and Ind.*, **45,** 300 (1926).—Owing to increasing consumption of Al in France, the prohibition is foreshadowed of the export of bauxite. In 1924, French exports of bauxite totalled 202,000 tons. H. H. S.

Efficiency plus. ANON. *Brick and Clay Rec.*, **68** [11], 860–65 (1926).—The new plant of the A. P. Green Fire Brick Co. at Mexico, Mo., is described. The plant was designed by H. L. Pearson and has operated continually since starting. The plant is built around the New Harrop tunnel kiln. Only dry press brick are made. The brick are dried by waste heat from the cooling zone of the kiln. Only ¼ the time is required to produce a finished brick, as compared with the old method. R. E. G.

Study of silica bricks. Dilatometric analysis. Testing of the raw materials. TRAVERS AND DE GOLOUBINOFF. *Rev. métal.*, **23,** 27–47, 100–17 (1926).—After a review of the development of SiO_2 bricks and of the properties, prepn. and transformations of the 4 varieties of anhyd. SiO_2, T. and de G. describe in detail their own expts., carried out with the Chevenard differential dilatometer. The expansion curve of cristobalite exhibits, in the neighborhood of 210°, a practically instantaneous and reversible anomaly, which is greater than had been admitted to date; consequently, the total expansion above 210° is also higher (1.55 instead of 1.24). The expansion curve of tridymite, which was detd. up to 1100°, has 3 anomalies, of which only 2 had as yet been described, the 3rd, which is reversible, occurring at about 440–50° and corresponding only to a change in the law of expansion of this variety of SiO_2. Above 440°, the law of expansion of tridymite is practically linear, at least up to 1100°, and the expansion coeff. is very small. Contrary to Endell's conclusions, T. and de G. were unable to quench β-cristobalite and do not consider that his optical method for the detn. of tridymite in presence of cristobalite is applicable. The dilatometric method has been applied to the detn. of the constituents of SiO_2 bricks: it is simple, gives easily interpreted results, and has revealed the presence of amorphous SiO_2 in a no. of common products. MacDowell's objections to the method, *viz.*, porosity, action of fluxing impurities (Fe and alkalis, mainly), and poor heat condy., are shown not to interfere sufficiently in ordinary cases to prevent obtaining fairly accurate and valuable results. If a is the expansion anomaly at 210°, a' the total anomaly at 115° and at 145°, and a'' the anomaly at 570°, then % cristobalite $= 100\ a/1.05$, % tridymite $= 100\ a'/0.26$, and % quartz $= a''/0.27$. The most important detns. in the chem. anal. of the raw mats. are fluxing impurities (alkalis and Fe_2O_3). Examn. of thin sections of the raw mats. under the polarizing microscope allows of noting the distribution of the impurities, and if the distribution is irregular the mat. should be ground sufficiently fine to ensure even distribution. One of the most important tests is the detn. of the expansion, but it is preferable to study the expansion of the constituents after firing, rather than measuring total increase in vol. after firing, as recommended by Wernicke, which does not take into account the contraction of the quartz on becoming amorphous prior to transformation into tridymite. The preliminary conversion of quartz into amorphous SiO_2 is confirmed by dilatometric measurements carried out after repeated firings at

1050–1300° (described in detail). Working under identical conditions (which are described in detail), the rise in temp. on dissolving SiO_2 in fused anhyd. KOH at 300° was found to be: about 29° for quartz, 40° for tridymite, 44° for cristobalite, and 48° for SiO_2 glass and pptd. SiO_2, the results being accurate to within 1° (*C. A.*)

Service of kiln linings. ANON. *Rock Products*, **29**, [4], 82–3 (1926).—Cement-kilns lined with "Arcofrax," a high-alumina diaspore clay brick, gave much longer service than kilns lined with ordinary high-grade fire clay. (*C. A.*)

Fireclay brick, their manufacture, properties, uses, and specifications. ANON. Bur. Standards, *Circ.* No. **282**, 50 pp. (1926).—A brief history of the manuf. and of the growth of technical research. Raw mats., methods of manuf., and classification, properties, and uses of the finished product are described. The U. S. Government Master Specification for fireclay brick is given. (*C. A.*)

PATENTS

Casting slip. HARRY TRISTRAM BELLAMY. U. S. 1,585,010, May 18, 1926. A casting slip consisting of finely divided silicon carbide, refrac. clay, a deflocculating agent, and sufficient water to give the mixt. a specific gravity of 2.25.

Production of refractory oxide ware. JOHN WESLEY MARDEN. U. S. 1,585,779, May 25, 1926. An article of manuf. composed of thoria and resulting from shaping and firing a mixt. of thoria, cryolite, phosphoric acid, and water.

Refractory and ceramic process and material. ANSON G. BETTS. U. S. 1,585,827, May 25, 1926. Refrac. ceramic mix consisting of refrac. comminuted acid-insoluble mat. wetted with a soln. containing basic aluminum halide.

Composition of matter and method for making the same. WILLIAM W. WINSHIP. U. S. 1,587,057, June 1, 1926. An article of manuf. comprising comminuted fused silica and silicic acid.

Zirconium-oxide compound and method of making same. CHARLES J. KINZIE. U. S. 1,588,476, June 15, 1926. A zirconium oxide compd. characterized as being a calcined product, of specific gravity of about 5.00, essentially white in color, as consisting by anal. preponderatingly of unfused zirconia and containing also a less quantity of commingled basic and acid-forming ingredients.

Method of making carborundum structures. JAMES KELLEHER. U. S. 1,588,473, June 15, 1926. The method of uniting two pieces of silicon carbide which comprises htg. them in contact with one another to a temp. of approx. 1800°C or over, in a non-oxidizing atmosphere.

Terra Cotta

Interferometer measurements of the thermal dilatation of glazed ware. G. E. MERRITT AND C. G. PETERS. *Jour. Amer. Ceram. Soc.*, **9** [6], 327–42 (1926).—The network of fine cracks often seen in the surface of glazed products not only mars the surface but shortens the life and lowers the price of the ware. Since the relative expansivity of the glaze and body is a very important factor in controlling this condition, reliable meas. of both are of the utmost importance. Until recently the difficulty has been that the expansivity of the glaze has been measured on specimens of the mat. melted to glass and drawn into rods or cast in molds of sufficient length. Owing to the difference between this treatment and that received by the mat. when spread on the ware, it was realized that these methods might lead to unavoidable errors. By the interference method, specimens 0.2 mm. in length can be measured with sufficient accuracy. Therefore in measuring glazes the samples may be taken directly from the finished ware. In this paper the thermal expansion of glaze mats. prepared in the form

of drawn glass or cast rods is compared with that of the same mat. taken from the finished ware. From the meas., the expected divergence is found to be as much as 20% in the case of drawn glass specimens, and 10% for cast specimens.

Recent factory experience and experiments in drying terra cotta. JAMES R. BOWMAN. *Jour. Amer. Ceram. Soc.*, **9** [6], 380–91 (1926).—An attempt was made to det. by expt. the best conditions with respect to temp., circulation of air, and its relative humidity, by which to obtain shorter drying time, a minimum of warpage, and cracking of the ware generally. Also, a very tender clay was given special study with the object of finding a set of drying conditions by which its extreme tendency to warp and crack would be reduced to a point that would permit practical use of this clay for terra cotta body. The drying time was reduced about 40% by increasing the steam press. in the htg. coils and apparently some showing made in reducing the tendency of the ware to warp and crack. A schedule of drying that gave satisfactory results with the tender clay was developed on an experimental scale, but could not be applied to the factory driers because of limitations in the heating and circulation equipment.

Notes on green scumming. EARL R. CURRY. *Jour. Amer. Ceram. Soc.*, **9** [6], 392–97 (1926).—A description of a green scum formed on brick made from a California clay. Anal. showed vanadium oxide as the principal colorant. Tests of scum prevention were made by adding various compds. to the green body or by dipping the finished piece into solns. of various salts. Several promising methods of scum prevention are indicated.

White Wares

The electrical resistivity of some ceramic materials at elevated temperatures and a simple commercial method for its determination. ROBERT MAYNARD KING. *Jour. Amer. Ceram. Soc.*, **9** [6], 343–50 (1926).—This paper gives the values obtained by some resistivity meas. of several well known minerals used in the ceramic field. The values for some ceramic bodies are also given. A simple app. and method with which these values were obtained are described in detail.

The permissible moisture content in ball clay shipments. ARTHUR S. WATTS. *Bull. Amer. Ceram. Soc.*, **5** [6], 286–90 (1926).—The Ball Clay Data Comm. of the White Wares Division was created by popular vote of both shippers and buyers and its mode of procedure detd. by a questionnaire sent out to both shippers and buyers. The mode of procedure is as follows: (1) the normal water content shall be detd. by actual tests on samples of wet, normal, and dry ball clays; (2) the samples to be tested shall be obtained from the consumer without consulting the shipper; (3) ball clays shall be classified on both raw color and a viscosity basis; (4) foreign and domestic ball clays shall have separate classifications. W. gives results obtained in tests run to det. the practicability of this procedure and offers for consideration specif. for max. and minimum permissible moisture contents of the various kinds of ball clays. E. J. V.

Face a clay shortage. ANON. *Pottery, Glass and Brass Salesman.*, **33** [14], 27 (1926).—Due to the strike in England, shipments of clays from there are held up and this leaves the ceram. industry in the East Liverpool district facing almost complete paralyzation if the strike continues. E. J. V.

Pottery making in the olden days and now. WILLIAM BRAGG. *Pottery, Glass and Brass Salesman*, **33** [15], 27 (1926).—A brief résumé of a lecture on the "Trade of the Potter." E. J. V.

Mechanical strength tests on electric porcelain. HANS HECHT. *Trans. Ger. Ceram. Soc.*, **6** [3], 123 (1926).—A preliminary report on expts. leading to the testing of porcelain under conditions of tensile, bending, and compression strains with the aid of polarized

light. This would do away with the errors and variations caused by irregularities and varying shapes of the test pieces. The suggestion is made to construct a test piece of the shape of a stand. insulator out of some transparent mat. absolutely devoid of internal strain and then examine it under polarized light when subject to the strains developed in service. An examination under these conditions would det. whether the piece was so designed as to give the greatest strength where most needed. F. A. W.

Isolantite—a remarkable ceramic material. AUSTIN C. LESCARBOURA. *Ceram. Ind.*, **6** [6], 575–82 (1926).—Isolantite is a very finely ground mineral which may be pressed with hydraulic press., using a gas as a catalyst, into blanks or blocks, which may be machined to the desired shape. When fired to 700°C, the mat. is soft and has ability to withstand temp. changes. When fired to 1500°C, and held for 60 seconds, the mat. has a hardness of 9.5. It is claimed that isolantite has many desirable features such as high dialectric, great strength, etc. R. E. G.

Safeguarding of industries. ANON. *Chem. and Ind.*, **45,** 334 (1926).—The British Pottery Mfrs. Federation, on behalf of the china section of the industry, has lodged a formal application for an enquiry under the S. of I. Act, with a view to the imposition of an import duty on foreign pottery. Foreign competition, particularly from Czechoslovakia and Germany, has been growing, and it is said that but for the export trade many Eng. china plants would not be working. H. H. S.

Meissen porcelain. ANON. *The Times* (London), April 29; *Chem. and Ind.*, **45,** 334 (1926).—The Meissen factory at Dresden has had to apply to the Saxon Govt. for a subsidy on account of the continuous difficulty in finding markets for its expensive products. H. H. S.

Recent researches on porcelain. E. E. URBSCHAT. *Z. angew. Chem.*, **39,** 365–68 (1926); *Chem. and Ind.*, **45 B,** 361 (1926).—Review is made of the m.p. diagram for Al_2O_3–SiO_2 mixts., of the influence of various types of quartz on phys., optical, and mech. properties of porcelain, of colors and glazes, and of the factors governing the durability of saggers. H. H. S.

BOOK

STEINBRECHT, GUSTAV: **Die Steingut-Fabrikation.** Vol. I. Vienna: A. Hartleben. 260 pp. R. M. 5.

Equipment and Apparatus

Machines used in magnetic separation. B. I. ROLLING. *Chem. and Ind.*, **45,** 344–45, 352–55 (1926).—R. remarks on the paucity of literature on this subject. He divides the uses of magnetic sepn. into: (1) removal of iron from clay, grain, sugar, chemicals, etc.; (2) concn. of weakly magnetic ores; (3) slag reduction and reclaiming unburnt coal. The paper is well illustrated. The machs. mentioned by name are Wetherill, Christy, Rapid, Igranic, Krupps, and Ding. H. H. S.

Standard wire screens: proposed British table. O. C. ELLINGTON. *Chem. and Ind.*, **45 T,** 128–34 (1926).—The U. S. standard sieves, issued by Bur. of Stand. (*L. C.* 74), do not meet the requirement that the ratio A/W, aperture: wire-diameter, shall be constant all through the series from coarse to very fine. Their screening area is 62% in the coarse (No. 4) and only 30% in the finest (No. 325). Another system of sieves, that of the Inst. Mining & Metall., has a constant screening area but it is very low, only 25%. Also, the intervals between each grade of sieve are large and irregular. The proposed new table eliminates these and many other disadvantages. H. H. S.

BOOK

Vacuum Practice. L. DUNOYER. Transl. by J. H. SMITH. Pp. 238. London: G. Bell & Sons, 1926. Price 12 *s* 6 *d*.

PATENTS

Process of drying clays and similar materials. T. H. RHOADS. U. S. 1,587,419, June 1, 1926. The method of drying ceram. articles, which consists of introducing the articles, in a wet condition, into a drying compartment; raising the wet bulb temp. of the compartment to a point close to the wet bulb temp. of the article; gradually drying the article by increasing the dry bulb temp.; then reducing the dry bulb temp. and the wet bulb temp. approx. to the dew point, to permit a flow of moisture from the interior of the article to the slightly drier surface thereof and a uniform temp. of the article throughout its bulk to ensue; then progressively increasing and maintaining the wet bulb temp. of the air to and at a point slightly in excess of the article wet bulb temp. and increasing the dry bulb temp. of the air slightly in excess of the wet bulb temp. thereof, until the desired degree of dryness of the article is obtained.

Apparatus for testing hardness of metals or other substances by impact. C. E. DAHLQVIST. U. S. 1,581,839, April 20. (*C. A.*)

Kilns, Furnaces, Fuels, and Combustion

Pulverized fuel risks. ANON. *Chem. Age*, **14**, 470–71 (1926).—Reference to report of U. S. Bureau of Mines on proper precautions in use of powdered fuels. To avoid danger of spontaneous combustion, pulverized coal at 150°F, or higher, should not be stored in a bin for more than 18 hrs. E. E. P.

Electrical resistance furnaces. W. B. CLEMENTS. *Chem. Age*, **14**, (355), Suppl., 27 (1926).—Elec. resist. furs. have become popular in recent years because they may utilize 90% of the heat generated, and are easily subjected to temp. control. Platinum was first used as a htg. element by Heraeus in 1902, but it is not satisfactory because of its high cost and its increase in resist. with temp. rise. Pure nickel was tried in 1907, and was found quite serviceable up to 900 to 1000°C. Nickel-chromium alloy (nicrome) was introduced in 1907, and is now generally used of compn. 80% nickel and 20% chromium. It may withstand 1100°C for 1000 hrs., and 1200°C for 50 to 60 hrs. For higher temp., no satisfactory htg. element has been found. Molybdenum or tungsten have high m. ps., but oxidize rapidly in air and hence require an atmosphere of hydrogen. Carbon has a high melting point, but begins to oxidize at 600°C. A special form of silicon carbide (silit) rods have proved more successful than rods of ordinary carbon or graphite. E. E. P.

Kilns for the firing of silica and clay fire brick. W. GRUM-GRJIMAJLO. *Feuerfest*, **2** [2], 13 (1926).—Detailed description with illustrations is given of (1) 4 chamber regenerative gas kiln with the chambers in series, (2) 5 chamber gas kiln round type. These kilns were especially designed for the firing of silica brick following certain hydraulic theories advanced by G. F. A. W.

Insulation of periodic kilns. M. LEBON. *Corr. dei Ceramisti*, **7**, 6 (1926).—Heat losses that are eliminated by insulating kilns with various mats. were enumerated and the saving effected is noted. S. S. C.

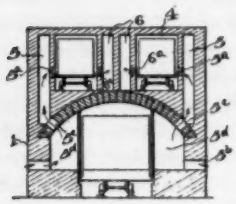
Ceramic kilns in 1925. S. R. HIND. *Fuel Economy Rev.* **5**, 26–30 (Mar., 1926).

BOOK

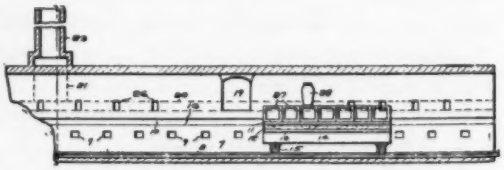
Gas and fuel analysis for engineers. A. H. GILL. Tenth ed. New York: John Wiley and Sons, Inc., 1925. H. H. S.

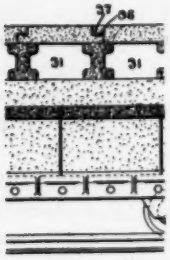
PATENTS

Tunnel kiln. G. W. BOOTH. U. S. 1,585,013, May 18, 1926. The combination of a tunnel kiln; a separate drying chamber arranged at the top of the kiln whereby the chamber will be heated by conduction from the kiln; an air passage formed longitudinally in a wall of the chamber and adjacent the kiln, the passage having a series of openings communicating with the interior of the chamber; a moist air flue extending longitudinally of the kiln communicating with the interior of the chamber; and means for drawing air through the said passage, chamber, and flue.



Kiln for firing earthenware. W. L. BURLEY. U. S. 1,585,015, May 18, 1926. In a kiln for firing earthenware, a long kiln casing having side walls forming a longitudinal tunnel, said tunnel having an intermediate baking zone and pre-heating and cooling zones disposed upon opposite sides of the baking zone, fire boxes arranged upon opposite sides of the tunnel adjacent to the baking zone and discharging directly into the baking zone, said side walls having longitudinal flues formed therein and also in the walls of the fire boxes, said longitudinal flues extending throughout the major portion of the length of the pre-heating zone and the cooling zone, a stack arranged adjacent to the outer end of the pre-heating zone and in communication with the ends of the longitudinal flues, the pre-heating zone having the major portion of its length arranged between the stack and the baking zone, the side walls of the tunnel in the pre-heating zone having transverse flues which lead from the tunnel to the longitudinal flues, the side walls of the tunnel in the cooling zone also having transverse flues leading from the tunnel to the longitudinal flues, said longitudinal flues having their ends adjacent to the cooling zone open to the atmosphere and their ends adjacent to the pre-heating zone closed to the atmosphere, said longitudinal flues being free from direct communication with the fire boxes.





Tunnel-kiln car. M. F. BEECHER AND A. E. OLSON. U. S. 1,587,210, June 1, 1926. A car for tunnel kilns comprising a supporting framework mounted on wheels and a super-structure thereon having a layer of refrac. blocks so constructed and arranged that they may expand under the influence of heat and upon cooling will pull each other back to their original positions.

Geology

Kaolin in Texas. E. H. BROWN. *Ceramist*, **8** [1], 34–37 (1926).—American potters and chinaware manufacturers have long been dependent upon foreign countries for the bulk of their supply of kaolin, in 1924 importing about 315,000 tons valued at $3,190,000. The U. S. has a valuable and practically inexhaustible supply of kaolin in Texas and other southern states. It has been amply demonstrated that the American kaolin is of far superior grade in certain respects than the best that England produces. Foreign kaolin contains a large amount of deleterious matter. B. gives anal. to show the purity of the American kaolin. B. describes a deposit of kaolin in stratified beds in Real County, Texas, which is virtually unlimited and gives a short history of its develop-

ment. Litigation involving the boundaries of the land over a long period of years prevented marketing of the mat. B. points out the opportunities in connection with this deposit, discusses the freight rates to mfg. points and the possibilities of starting a chinaware plant in Dallas. A. E. R. W.

Georgia clays, properly handled, suitable for making chinaware. ANON. *Pottery, Glass and Brass Salesman*, **33** [14], 26–27; [17], 26 (1926).—A brief résumé of the contents of Bureau of Mines Bull. 252, "Beneficiation and Utilization of Georgia Clays" by R. T. Stull and G. A. Bole. Washed Georgia clays can be used to advantage in vitrified ware, displacing all or part of the English china clays. E. J. V.

BOOK

Physical geography of Georgia. L. LAFORGE, etc. Atlanta: Geol. Surv. Bull., 1925. H. H. S.

Chemistry and Physics

Influence of alkalis, acids, and salts on the plasticity of kaolin. M. JACOBY. *Trans. Ger. Ceram. Soc.*, **6** [3], 97 (1925).—The action of alkalis (in this instance caustic soda) on plastic clays is similar to their action on slip but less pronounced and by their addition plasticity can be raised to a certain extent. Tannic and ulmic acid increased plasticity to a certain point by increasing colloidal contents. Muriatic and acetic acid and sodium chloride reduced the plasticity, shrinkage, and dry strength. Tests of these three properties on treated kaolins gave entirely analogous results which would show that OH-ions and colloids increase plasticity to a certain max. and H-ions reduce it. Shrinkage and dry strength are closely related to plasticity and could be used as a meas. of it. F. A. W.

Plasticity determinations of kaolins and clays. R. RIEKE AND E. SEMBACH. *Trans. Ger. Ceram. Soc.*, **6** [3], 111 (1925).—Discussion of recent work by K. Pfefferkorn based on the assumption that the water content of a properly prepared clay bears a constant relationship to the plasticity. Author took 5 clays covering a wide range of plasticity and to them added finely ground flint in varying proportions and made deformation tests according to the Pfefferkorn method. The results showed that prepared clays of low plasticity with a high percentage of flint added actually had a higher water content than the plastic clays, which is directly opposed to the theory advanced. F. A. W.

Velocity of thermal decomposition of carbonates. B. BRUNS. *Jour. Phys. Chem.* **30** [5], 680–93 (1926).—The velocity of decomposition of various carbonates was detd. by heating the sample in a tube sealed at one end and connected to a closed vessel containing mercury and provided with an overflow pipe. The evolution of CO_2 depressed the mercury surface and caused mercury to flow out of the overflow pipe, the volume of which was a measure of the CO_2 evolution. Ferrous, lead, cobalt, zinc, and mercurous carbonates decomposed at rates found valid for homogeneous unimolecular reactions. The mechanisms of decompn. of these substances are derived. The "critical increments," detd. from the dependence of the reaction constants on temp., approx. 80,000 calories, and seem characteristic of the carbonate ion in the crystal lattice. Synthetic ferrous carbonate gives a lower value due probably to the catalytic action of water. E. E. P.

Porosity and specific gravity of refractory materials. E. PRESSLER. *Corr. dei Ceramisti*, **7**, 3–5 (1926).—The article describes the various methods of detg. porosity and gravity and the accuracy of each method brought out. Reasons for air porosimeter being the best are given. S. S. C.

Determination of boiling point of $SiCl_4$. J. MALUQUER CUETO. *Quim. e Ind.*, **3**, 85 (1926).—Historical review of former data on subject. Method of obtaining

$SiCl_4$ from FeSi is given. Boiling pt. was 57.3°C. Latent heat of vaporization 46.1 cal./g. S. S. C.

X-ray diffraction patterns of mullite and of sillimanite. R. W. C. WYCKOFF, J. W. GREIG, AND N. L. BOWEN. *Am. Jour. Sci.*, **11,** 459–72 (1926).—The data on sillimanite fit a unit cell contg. two mols. of $Al_2O_3 \cdot SiO_2$, but this cell would contain only $\frac{3}{4}$ mol. of mullite ($3\ Al_2O_3 \cdot 2\ SiO_2$). In view of this impossibility it is suggested that the true unit cell of mullite, and presumably also of sillimanite, is larger. Such a larger unit might contain 3 mols. mullite or 8 mols. sillimanite. H. H. S.

Geochemical relations between petroleum, silica, and water. P. G. NUTTING. *Econ. Geol.*, **21,** 234–42 (1926).—Silica can act not only as filter for color and saturation, and break up saturated hydrocarbons like paraffin, but it may act as catalyst in producing and maintaining equilibrium between the various components of petroleum. H. H. S.

Crystal structures of anatase and rutile, the tetragonal forms of TiO_2. M. L. HUGGINS. *Phys. Rev.*, **27,** 638 (1926).—The symmetry of the arrangement of Ti and O atoms in anatase is that of the space group D_{4h}^{19} (4 Di-19); and of rutile D_{4h}^{14} (4 Di-14). H. H. S.

Adsorption capacity of soils. E. BOBKO AND D. ASKINASI. *Trans. Russ. Inst. Fertilisers*, Lief 25 (1925); *Chem. and Ind.*, **45 B,** 415 (1926).—The bases originally present are displaced by means of $BaCl_2$, and the adsorbed Ba is extracted with $N/20$ HCl, or, in the case of soils contg. much $CaCO_3$, with N NaCl. The Ba is then estimated. The results obtained by this method are higher than by the amm. chloride method of Gedroiz. The adsorptive capacity of soils is changed in varying degree by this treatment; in black soils, it is reduced about 42% after 4 expts., while a Podsol soil was hardly changed at all. H. H. S.

Apparent paradox of plasticity. A. DE WAELE. *Koll.-Ztg.*, **38,** 257–59 (1926); *Chem. and Ind.*, **45 B,** 391 (1926).—In using the plastometer it is necessary to have sufficiently wide tubes for the test. Otherwise, the figures obtained are lower than those given by the viscosimeter, because when capillary tubes are used, the size of particle of the disperse phase becomes comparable with the radius of the tube. H. H. S.

Adsorption from solution. T. SABALITSCHKA AND W. ERDMANN. *Pharm. Ztg.*, **71,** 374–76, 390–92 (1926); *Chem. and Ind.*, **45 B,** 419 (1926).—Comparative expts. on adsorption of $BaCl_2$, $FeCl_3$, Al acetate, KOH, HCl, HOx, HAc, iodine, and many other solns., by kieselguhr, boneblack, $BaSO_4$, lime-charcoal and other charcoals, show that the order of adsorptive power varies. Generally, animal charcoal, charcoal sponge, and boneblack, possess the highest, and $BaSO_4$ the lowest power, but the best adsorbent for bases, boneblack, is inferior to lime- and animal-charcoals for acids. H. H. S.

Weighing. W. A. BENTON. *Chem. and Ind.*, **45,** 299 (1926).—Extreme sensitivity is by no means the most important quality in a chem. balance. Accuracy and uniformity of operation are more vital. If chemists would more frequently test their balances for equality of arm-length by the methods of Borda or Gauss, they would occasionally make disquieting discoveries. Only conservatism prevents the introduction of a simpler and cheaper type of high-class balance in which no error due to arm inequality can arise. H. H. S.

Volumetric determination of uranium, vanadium, copper, and iron in uranium ores. A. S. RUSSELL. *Chem. and Ind.*, **45 T,** 57–60 (1926). H. H. S.

Kaolin and its thermal changes. K. A. VESTERBERG. *Ark. Kemi, Mineral. Geol.* **9,** [14], 26 pp. (1925).—Subjecting kaolin to higher temps. has a marked effect upon its soly. in HCl. Normally, kaolin is only slightly sol. In the pre-heating range

of 400° to 500° the soly. increases enormously (parallel to the loss of chem. bound H_2O), stays const. between 600° and 800° corresponding to nearly complete soln. of the entire Al_2O_3 content, and decreases very rapidly after 900°, while preheating to 1000°, or higher, results in almost complete insoly. Data obtained with a sample of china clay are in accord with the results of Sachsse and Becker (*Landw. Versuchs-Sta.* **40,** 246(1892)) except that the numerical values of the characteristic temps. are somewhat different. Several previous investigators have claimed that the increase in soly. is due to the decompn. of the kaolin ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) into Al_2O_3 and $2SiO_2$, as the $2H_2O$ is removed by heating, and part of the present invest. is devoted to a study of this supposition. By investigating the solubilities in 5% Na_2CO_3 soln. and in HCl of heated Al_2O_3 and SiO_2, separately and in intimate mixt. and by comparing the results thus obtained with similar expts. on china clay and crude kaolin, the definite conclusion is arrived at that kaolin does not decompose into its free constituents by heating to 500° to 800°, but that a new anhyd. silicate, $Al_2Si_2O_7$, is formed. This new silicate is characterized by its soly. in HCl. After dissolving the Al_2O_3 from the heat-treated silicate, it is found that the remaining SiO_2 is strongly hydrated, contg. 9% water, a result which supports the compd. theory. Studies of the sp. grs. involved also count against the idea of a decompn. into Al_2O_3 and $2SiO_2$. Similar studies of the mineral glagerite, of the supposed formula $2Al_2O_3 \cdot 3SiO_2 \cdot 6H_2O$ or $Al_2O_3 \cdot 2Si O_2 \cdot 2H_2O$ + aq. lead to the conclusion that it is actually a mixt. of about equal amts. of real kaolin and an aq. Al_2O_3 silicate sol. in HCl. Neither does the mineral pyrophyllite, $Al_2O_3 \cdot 4SiO_2 \cdot H_2O$, contain any free SiO_2, and no free SiO_2 is formed by heating. The soly. of the latter mineral in HCl increases only slightly by heat treatment, and it is therefore suggested that the kaolin may be removed from mixts. of kaolin and pyrophyllite by heating the mixt. to 750° followed by successive treatments with HCl and dil. KOH. Finally, a somewhat modified method is worked out for the detn. of kaolin in clays, the essential steps in this process being (1) the original sample is boiled with HCl, (2*a*) part of the undissolved mat. from (1) is subjected to the same treatment once more while (2*b*) part of it is heated to 600–800° and then treated as (2*a*). The analyses of various clays according to this method are given. (*C. A.*)

Kaolins, clays, etc. Formation of clay shales containing carbonaceous products. A. Bigot. *Compt. rend.* **182,** 634–35(1926).—Theories of formation are discussed. (*C. A.*)

Studies on the system calcium oxide-ferric oxide-silica. W. C. Hansen and R. H. Bogue. *J. Am. Chem. Soc.* **48,** 1261–67(1926).—A study of 3 fields in the CaO–Fe_2O_3–SiO_2 system has been made and equil. diagrams have been drawn. No optical evidence of the existence of ternary compds. was found but the existence of $3CaO \cdot SiO_2$ was confirmed. The inversion of $2CaO \cdot SiO_2$ to the γ-form takes place in cooled charges of CaO–Fe_2O_3–SiO_2 except where the concn. of the CaO–Fe_2O_3 compds. is high. Fe_2O_3 in Port. cement may be present as cryst. $2CaO \cdot Fe_2O_3$ or $CaO \cdot Fe_2O_3$. (*C. A.*)

The density of boric oxide glass and the suspected variation in the atomic weight of boron. H. V. A. Briscoe, P. L. Robinson and G. E. Stephenson. *J. Chem. Soc.* **1926,** 70–9; cf. *C. A.* **19,** 1512, 1971.—Previous study of the ratio of BCl_3 : 3Ag for B obtained from minerals found in widely sepd. parts of the world indicated a significant variation in the at. wt. of B. The present detn. of the d. of B_2O_3 glass beads confirms those results. The mean d. of B_2O_3 is 1.7952, the commonly used value 1.88 being in error. The at. wt. of B from different parts of the world varies from 10.788 to 10.847. The max. error of the individual detns. is 0.005. The d. was detd. by a *new flotation method for the d. of solids.* The temp. of flotation of beads of B_2O_3 in a mixt. of pentachloroethane and trimethylene dibromide was observed and the d. and thermal expansion of the liquid mixt. were detd. separately. (*C. A.*)

Atomic dimensions. R. G. LUNNON. *Proc. Phys. Soc.* (*London*), **38,** 93–108 (1926).—A review with extensive bibliography of 22 methods of estn. of at. diams. These include at. vols., X-ray anal., viscosities, equations of state, diffusion, compressibility, latent heats, ionization potentials, optical rotation, mol. films, etc. The results are fairly concordant. Each inner electron shell is about 0.25 A. U. thick. (*C. A.*)

Remarks on the methods for electrometric p_A determination. HEINRICH MENZEL AND FRANZ KRÜGER. *Z. Electrochem.*, **32,** 93–7 (1926).—Some practical directions. *A H-electrode* is described suitable for the detn. of p_H in small samples of solns. (*C. A.*)

The puncture of solid dielectrics. A. F. WALTHER, L. D. INGE AND N. N. SEMENOV. *Trans. Phys. Tech. Lab. Leningrad* **100,** 51–63 (1925).—The authors review Wagner's thermal theory of the mechanism of puncture of dielectrics and, after further development of the theory, they compare the predicted values of the breakdown-voltage with the results obtained on rock salt exptly. At high temps. (500–700°) the observed effects of temp. and thickness of the dielec. agree fairly well with theory. However, the theory fails at lower room temps. (*C. A.*)

Equation of state of solids (metals), cohesion and pressure and temperature coefficients of cohesions. J. J. VAN LAAR. *Verslag. Akad. Wetenschappen Amsterdam* **34,** 1303–20 (1925).—Mathematical discussion. The equation $p+(a/v^2)=(\lambda+RT)/(v-b)$, analogous to that of van der Waals, is shown to explain satisfactorily the temp. and pressure coeffs. of cohesion in solid metals. (*C. A.*)

The silicides of calcium and magnesium. L. WÖHLER AND O. SCHLIEPHAKE. *Z. anorg. allgem., Chem.*, **151,** 1–20 (1926).—Thermal analyses were made on mixts. of Ca and Si and of Mg and Si at high temps. Special app. was made, the crucible mat. being of bole and alumina in the ratio 5 : 2, this mat. withstanding a temp. up to 1560° without softening. The Ca-Si system shows the formation of a compd., $CaSi_2$ (41.6% Ca), which Tamaru had predicted by thermoanalytical work with inferior app., f. p. 1020°. The presence of the monosilicide CaSi, m. 1220°, prepd. previously by Wöhler and Muller, was also confirmed. In addition, the presence of another silicide, Ca_2Si, f. p. 920°, was indicated, though on account of its instability it was difficult to study. Of the 2 silicides, CaSi and $CaSi_2$, the former, formed at higher temp., is the more unstable and is easily transformed to the more stable $CaSi_2$. Potential measurements, which gave evidence in every case of the existence of 3 different Ca silicides, supported the thermoanalytical results. Only 2 Mg silicides were found, Mg_2Si, previously discovered by Vogel, and MgSi. The former was produced by the slow cooling of the Mg-Si melt contg. excess Mg, the Mg_2Si contg. 63.2% Mg. Above 800° Mg vaporizes and the monosilicide, MgSi, 46.2% Mg, is formed, along with more complicated silicides and free Si. The region of stability of MgSi lies probably in the liquid phase above 1050°. Small quantities of MgSi were obtained by chilling this melt below 600°, while above this temp. it slowly goes over to Mg_2Si, the more stable compd., this latter on further heating passing through the stage MgSi, and finally to the end products, the elements. (*C. A.*)

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PATENTS

Ceramic and refractory making process and material. A. G. BETTS. U. S. 1,585,826, May 25, 1926. Process of bonding and purifying an iron-containing acid-insoluble refrac. base, which consists in mixing therewith and thereafter heating therewith hydrated basic aluminum chloride, and volatilizing iron chloride therefrom.

Base-exchange silicate and process of making it. H. J. WHEATON. U. S. 1,586,764, June 1, 1926. A double base exchange silicate in which practically all of the sol. sub stances formed by reaction of the constituent solns. are retained in the gel.

Treatment of clay. W. FELDENHEIMER. U. S. 1,588,956, June 15, 1926. The process for the treatment of clay which comprises subjecting the clay in aqueous suspension to the action of a plurality of bleaching agents the coöperative effect of which is greater than the sum of their individual effects.

General

Address of retiring president. E. WARD TILLOTSON. *Bull. Amer. Ceram. Soc.*, **5** [6], 263–68 (1926).—A review of the activities of the AMER. CERAM. SOC. during the twenty-seventh year of its organization, suggestions to be considered by the SOCIETY, and an examination of methods of serving objects by it are presented. The need for coöperation is emphasized. E. J. V.

Leader in ceramics: Albert Heinecke. ANON. *Keramos*, **5** [3], 131–32 (1926).—A biographical sketch of Albert Heinecke, one of the foremost German ceramists of the century. E. J. V.

Some problems in the use of pulverized coal. A. G. CHRISTIE. *Power*, **63** [20], 748 (1926).—The rapid development of the use of pulverized coal has brought its problems. Dry coal is an advantage. Various classes of pulverizers are discussed. There is evidence that the ash content may aid combustion. Turbulence in the powdered-coal fur. is a desirable condition. Fur. temps. are limited in the older fur. with refrac. walls. Water cooled walls permit the highest fur. temps. possible. C. J. H.

The properties and testing of ceramic finished products—I. The relationship between the properties of ceramic products and their chemical composition. REINHOLD RIEKE. (Trans. by W. L. SHEARER AND A. W. HOLZMANN). *Ceramist*, **8** [1], 27–33 (1926).—*General.* The chem. and phys. behavior of a body is not entirely detd. by its chem. compn.; on the contrary, a number of other factors are of considerable importance. *Low fired bodies.* The role of iron, lime, and silica is discussed. *High fired bodies.* In the case of stoneware and porcelain, some properties, such as transparency and whiteness, are detd. principally by the mutual relationships between the cryst. and glassy constituents. A change in total compn. can affect these relationships in 3 ways. The mech. properties, such as brittleness, depend on the amount and behavior of the glassy ground mass. *Bodies for high temp. use.* R. gives the probable reasons for the favorable influence of small additions of lime, magnesia, and zinc oxide on the properties of bodies for high temp. use. The influence of iron and titanium on the body color is described. *Refractory materials.* Direct dependence on the chem. compn. is really to be observed only in the case of fusibility and this dependence is often obscured by purely mech. elements such as grain size. In some cases the chem. compn. of the bond is more important than that of the whole body. In such cases, the body should not be ground when its fusibility is being detd. None of the calcns. of fusibility based on anal. make an actual determination superfluous. The softening temp. is never an exact measure of the way in which a refrac. will behave in practice. *Con-*

clusions. R. points out the many difficulties encountered in comparing the properties of a body on the basis of their chem. anal., their batch weights, or their rational anal.
A. E. R. W.

The administration of industrial research. EDWARD R. WEIDLEIN. *Chemical News*, **132,** 365–66 (1926).—The Industrial Fellowship System of Mellon Institute, formulated in 1906, has stimulated the establishment of research labs. in indus. organizations. In establishing a research lab., adequate provision should be made for financial support, future expansion, and means for conducting both pure and tech. research.
E. E. P.

Recent research in fine grinding. G. MARTIN. *J. Chem. and Ind.*, **45 T,** 160–63 (1926).—An account of work done by the British Port. Cement Research Assoc. between 1923–1925. Grinding is claimed to be an exact mech. science with laws and methods of calcn. as definite as those of electricity or steam. Its importance is illustrated by the fact that the cost of grinding the annual Eng. output of 4 million T. of cement is over £1 million. To elucidate the laws of grinding, pure quartz sand was chosen. The following results were obtd.: *Law I.* (Rittinger's Law) Surface produced is accurately proportional to work done; double the work produces double the surface. *Law II.* The number of particles produced increases with decreasing diameter according to the compound interest law. $\text{Log}_e N = \text{log}_e a - bx$ where a and b are constants characteristic of the particular material ground, N is the number of partic'es, and x their diameter. *Law III.* The average shape of particles produced in crushing remains the same whether they are large or small. *Law IV.* The distribution of the numbers of different-diametered partic'es cannot be altered, no matter how often the sand is regraded.
H. H. S.

Meeting of English Ceramic Society *Chem. and Ind.*, **45,** 385 (1926). The annual meeting of the Ceramic Society was held at Stoke-on-Trent, on May 18. The membership is 675. Attention of members was drawn to the need for more contributions of papers dealing with practical problems, directed more towards opening discussions on difficulties in factories. The incoming President is George Turner. H. H. S.

New alloy steel. ROBERT HADFIELD. *Chem. and Ind.*, **45,** 386–87 (1926).—The discovery is announced of a new steel that will withstand abnormally high temps. A gas turbine wheel made of the steel has been tested at 55,000 revolutions per min., so that it was brought to a temp. of 800–900°C. At this bright red heat, its efficiency was not impaired.
H. H. S.

BULLETIN

of the

AMERICAN CERAMIC SOCIETY

A Monthly Publication Devoted to Proceedings of the Society, Discussions of Plant Problems, Discussions of Technical, Scientific and Art Questions and Promotion of Coöperative Research

Edited by the Secretary of the Society Assisted by Officers of the Industrial Divisions

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EDITORIAL

ADDRESS TO THE AMERICAN CERAMIC SOCIETY[1]

By Frank West

Had I consulted my own wishes alone, I should have come quietly to your meetings, listened to the papers in your interesting program and learned what I could of your knowledge and experience, but your energetic Secretary has put me down for an address, which I take to be a compliment to the English Ceramic Society, of which I have the honor to be President this year, and I will do my best to give you briefly a few ideas from the Old Country.

I should mention at the outset that I am more particularly associated with the refractory materials side of ceramics and specifically interested in the manufacture of silica refractories for use in high temperatures.

In my Presidential Address to the Refractory Materials Section of the English Ceramic Society in September last, I laid special stress on the value of research, and although, no doubt, many of you are in agreement with me as to the importance of research in our industry, you will forgive me if I touch very briefly on the same subject now.

The manufacturer of refractory materials is at a disadvantage as compared with a good many other manufacturers, in that he has no uniform raw material. His products are not standardized by composition. They are judged by their performance. Consequently, he must

[1] Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga., Feb., 1926.

take the particular material at his disposal and, by modifying his process, make the best of it.

This circumstance in itself increases the necessity for research in the refractory materials industry.

But the value of research, and of the men who are to carry it out, must be carefully scrutinized. One line of research may lead to success and another be quite futile. One man may quickly arrive at practical results, another may spend a great deal of time on elaborate experiments which lead nowhere. Really valuable research is that which proceeds on definite lines through a steady and patient accumulation of knowledge of the various processes by which we may improve or cheapen our products.

At the same time, the business man must not be too impatient when research institutions are slow in delivering results. Many blind alleys must sometimes be explored before a through-route to a definite result is found.

Many instances could be given of the benefits realized in the past by potters and refractory material makers through research. In the coal-gas industry, in which I have myself had a long experience, the striking developments of the past twenty years have been possible only because improved refractories became available as they were required, due chiefly to the special investigations of research carried out by the Ceramic Society and kindred bodies.

I learn from Dr. Mellor that you are fully alive to the value of research, and that you have some wonderful research institutions, which I hope to be permitted to look through during my short visit to this country.

It may interest you if I say something about the organization of ceramic research in England. In the first place, we have our Ceramic Society, which is divided into Pottery and Refractories Sections, each controlled by separate Councils. These Sections generally hold their meetings separately, but occasionally meetings are held in districts where there is matter for interest to both, and then the two Sections combine. For instance, in May, the Refractory Sections meet in Cornwall, the district of the china clay deposits, and it is expected that a large number from the Pottery Section will attend. Our Headquarters are in Stoke, the birthplace of English ceramics, and most of the research is carried out by the Stoke Laboratories under the control of our able and esteemed Honorary Secretary, Dr. Mellor.

The British Refractories Research Association, quite a separate concern for research only, is governed by a Council, in which manufacturers, users, and scientists are represented. This Association extends its research over the whole industry. Its headquarters are also

at Stoke, and its activities are under the direction of Dr. Mellor. This Association is supported by contributions from individuals and also by a government grant.

The Institution of Gas Engineers has also a Refractory Materials Committee, on the Council of which, besides the gas engineers, many of our important manufacturers of refractories are represented. The standard specifications of refractories for the gas industry are framed by this Committee. The experience of the gas industry at large is brought before it, and lines of research to be carried out are suggested. The efforts of the manufacturer are coördinated with the experience of the user.

There are several other research associations in connection with the iron and steel and other industries, in which refractories play an important part. All these associations are doing good work. They are centers for scientific and technical thought; through them the results of research are exchanged and discussed in all their bearings.

At the same time, each individual manufacturer must carry out a great deal of research into the properties and uses of his own raw material. As indicated before, there is almost infinite variety in the raw material, and private enterprise and individual initiative, are necessary to keep up the very high standard which is everywhere demanded.

The value of the work of research societies is greatly enhanced by visits to different works, particularly in other countries, and these are now being arranged on an increasing scale. Members thus keep in touch, not only with scientific advances, but also with actual technical practice, and so progress is made.

There was at one time some difficulty in getting manufacturers to see the advantage of throwing their works open to inspection, and of studying one another's methods, but I believe it is now generally admitted that the pooling of information is working to the advantage of all concerned. Users particularly should visit large manufacturers' works, get a better idea of the particular properties of the different products on the market, and apply them to their process to greater advantage than can ever be attained by the mere purchase of materials to specification.

Great meetings, Mr. President, like this one, bring together all the different sections of your SOCIETY. Individuals may discuss difficulties among themselves, not always for publication, and in many cases hints are given and received which lead to the solution of problems, to the advantage of the individual and of the industry as a whole.

I note that you have a very varied program of papers on all subjects, and I am pleased to see that visits to works in the district are also arranged.

In all countries, and even in these enlightened times, there are some manufacturers who are still working on the old rule-of-thumb methods of manufacture, but they surely must all in time modernize their works, and go in for scientific methods and research if they hope to keep in business.

In a good many instances brick-making plants, with a good raw material at their disposal, have not realized the best results, due to the lack of engineering knowledge and foresight in their initial lay-out. The lay-out of plant for the manufacture of refractory goods is an engineering problem, and I make special mention of this point because I have found in my own experience as Director of a concern producing refractory goods that my engineering training has proved of immense advantage in the design and development of the plant, and a big factor in the success of that particular concern. Engineering skill in the lay-out of the plant and steady scientific methods of control of the processes are essential to the success of any business which attempts to keep a foothold in the competition of to-day.

In conclusion, I wish to convey from the English Ceramic Society our best wishes to you all for the future progress of your SOCIETY and trust that the feeling of friendship and good fellowship which has always existed between our ceramic societies, may be maintained and extended in the future.

PAPERS AND DISCUSSION

AN OPINION ON THE RELATION OF GOOD DESIGN TO PROFIT IN THE GLASSWARE INDUSTRY[1]

By H. S. Nash

In an endeavor to suggest to manufacturers of glassware that a more careful analysis of what constitutes beauty in glass would be of profit to the industry, it should be stated that there is no intention to convey the impression that all glassware on the market is lacking in esthetic quality. Notably in table service there are many examples of pieces most satisfying as to line and color. Even among common containers (machine-made bottles), there are some not unpleasant to look at. However, there are quantities of glass carelessly or ignorantly designed; articles upon which some clever draftsman has imposed a wealth of meaningless ornament, whose lines are distorted to achieve the unusual, or which serve as a canvas, simply, for some pretty effect that will in a short time pall because of its insipidity and lack of character.

One unfortunate aspect of this situation is that there are manufacturers who are conscious that their product may be so described, but who honestly believe that were they to offer a line of true artistic merit its sale would be limited to a small group sensitive enough to appreciate its worth, and production would be seriously curtailed. It would be folly to argue the entire falsity of such an attitude since more than one manufacturer have made the attempt to prove this surmise.

The flaw seems to lie in the fact that instead of creating a product based on popular appeal and which conforms to the ethics of art, some manufacturers have, in all probability, employed a designer who creates for the esthetes. Such creations, though they approach art in its finest interpretation, are not to be included in this discussion since the writer unwillingly confesses that all men are not created equal in sense of appreciation, or any other sense. The work of very few great artists wins an immediate or a wide popularity, whereas the product of a factory must immediately find quantity sales. There is, however, within the province of the large or small manufacturer, a humbler interpretation of art, a loyalty to which would secure to the industry a more permanent foundation less liable to be shaken by whims of fashion or racked by feverish attempts to constantly supply novelties that die almost before they leave the factory.

This humble interpretation of art is simply this: that however popular an appeal an article may possess, it shall be honest to the character of glass, and it shall respect the ethics and spirit of glass decoration.

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[1] Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga. Feb., 1926. (Art Division).

The solution for quantity production of ware of artistic merit does not lie so much in the purchase of designs from eminent artists as it does in the employment of young men and women from the art schools of this country, who, with a natural feeling for and a training in what constitutes permanence in loveliness, can acquire in the factory a feeling for glass. Unhampered by factory traditions they will bestow on the product a freshness, a spontaneity and truthful appeal that articles which merely happen never can possess.

Essential Character of Glass Must Be Considered

Consider more specifically this conservative interpretation of art in glassware. First of all there is the essential character of glass to be considered. Glass, in the condition in which it is generally worked, is a plastic, viscous material capable of being blown or pressed into molds, but with a reluctance to produce sharp lines or angles. Whether or not articles so made of glass reflect such a character is the first test of their sincerity. Generally speaking, blown or pressed objects which suggest a hard mechanical accuracy, an elaboration of intricate detail, or a contour of complicated curves or abrupt angles are false to the nature of glass. Glass objects which suggest the intricate moldings of wood or metal, the sharply defined planes of stamped tin or the draped folds of a textile are no more than apologies for the material from which they are made.

There is no dishonesty in blowing a glass article into a fluted form or into some simple decorative relief. Glass is plastic and accommodates itself to the shape of an enclosing form. Should the mold, however, inflict on the object the realistic drapery of a textile the character of glass is shamed. A glass object may be banded in relief or in color without transgression but if the bands are to simulate metal strapwork the article is false. Imitation of other materials, or the imposing of the attributes of other materials upon glass is an apology for glass itself. It lacks sincerity, and if only for that reason it has no claim to art.

What matters more to the manufacturer is the fact that such apologies, however well their cleverness may induce a sale, will in the long run cheapen glass as a medium of expression and invite a revolt against it that may even seriously endanger parts of the industry. It is perhaps not unethical for glass that is actually cut to depend for its decorative effect upon sharply defined lines; nor can the imitation of such materials as amber and amethyst be classed as artistically unethical since the properties sought after belong naturally to both materials.

Ethics of Decoration

A respect for the ethics of decoration follows much the same reasoning as that accorded the material. Decoration is so often misunderstood

and misapplied. There ought not be any need for arguing that ornament however good looking in itself, applied to an object does not because of its own interest become a decoration. An article of glass well designed and made is a thing of beauty. Ornament, however lovely, that does no t make the object more beautiful as an object, that does not merge its personality with that of the article to which it belongs until it ceases to be noticed as a separate item of interest, is not decoration.

One of the faults common to all industries is the attempt to make one treatment of decoration imitate a different, more costly method. Aside from any question of ethics it fails artistically because it does not adequately accent the properties upon which the imitated technic depends for its justification.

Pressed flatware with an under surface patterned in delicately excised line becomes a beautiful thing of gauzy shimmering light. A great deal of present day imitation cut glass has little merit. Cutting or engraving on glass does not fit into quantity production methods without drastic sacrifice of good pattern or workmanship. Cut glass, provided it is not ostentatious, or sterile of imagination, is beautiful because it refracts light into a fascinating play of ever changing color. When pressed glass is made to imitate the cut article it has neither the mellow charm of the one, nor the scintillating brilliance of the other; it is nondescript.

Degree of beauty is not relative to the cost of producing it, a statement that seems to be more appreciated by people generally than by the manufacturers themselves. A piece, whether it be blown or pressed, cut, etched, engraved, decorated with a brush, decalcomania, print, or stencil, may in any case achieve distinction within its own honest limitations. No method of decoration has been exhausted of its possibilities, but altogether too many methods have been made to infringe cheaply upon commonplace interpretations of other methods. An apple is no less desirable or profitable to sell because it bears no resemblance to a grapefruit.

Decorations Follow Fashion Trends

The spirit of decoration becomes the special pursuit of the artist. It is good drawing. A successful artist in the manufacturing field must not only be able to create objects of beauty that can be made with a minimum of hand labor, but he also must be able to interpret the trend of fashion so that his creations become a necessity to the background which style creates. What people wear, what they read, and how they think are items not irrelevant to profitable designing of glassware. Colors and contours and patterns are the tools with which he expresses or causes glass to express the personality of the period in which he finds himself. And there has never been a better background

for honest, well interpreted glass; neutral, rough-textured walls, the naïve charm of hand woven and hooked rugs, the simple grace of Colonial furnishings or the dark rich note of Spanish or Italian style. There could be no better complement to such decorative schemes than glass in all its gleaming brilliance and color.

Let glassware become beautiful with the beauty of glass. Let its decoration serve only to enhance that beauty, subordinate in itself. Let contours cease to be arbitrary curves and achieve the personality of living things and there will be no need for an endless succession of novelties and thin "effects." The profit will lie in an assured stability from which springs growth.

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Port Jervis, N. J.

DISCUSSION ON "THE ATTACK OF ARSENIC COMPOUNDS ON FIRECLAY REFRACTORY MATERIAL"[1]

W.E.S. Turner[2] (communicated reply): I should like to express my thanks to Mr. McSwiney for his careful discussion of operating conditions in tank furnaces. He covers a great deal of ground and I do not think there is any need for me to traverse it again. The complication of factors which his discussion reveals emphasizes the desirability of carefully controlled experiments such as those which can best be carried out in pots. While the degree of corrosion of prepared samples of fire clay by batch materials and glass may vary according to the shape and nature of the fireclay form, no one would assert that fluorides or boric oxide or other specially corrosive substances lose their corrosiveness according as the batch containing them is melted in a tank or in a pot. A tank block may have a somewhat more open texture than a fireclay pot after both have been fired in their respective locations; but the higher average temperature of the pot walls and the much greater surface area per unit mass which a pot presents to the attack of glass or batch, as compared with tank block surface, should make a pot sensitive to the action of corroding agents. The fact that no marked evidence occurs of corrosion of fire clay by arsenic when tested in this way should, I think, make one hesitate to ascribe specially corrosive characteristics to arsenic in commercial tank melted glass.

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[1] *Jour. Amer. Ceram. Soc.*, 9 [7] 412–22 (1926).

[2] Received July, 1926.

NOTES ON AGALMATOLITH, A NEW REFRACTORY MATERIAL

By Oskar K. Burger

In the course of studies on soapstones in Brazil, a mineral apparently like the common material, but slightly harder was found. The chemical analysis gave the following results (average of different samples):

	Per cent		Per cent
Silica	63.01	Magnesia	0.15
Alumina	30.25	Ignition loss	6.12
Iron oxide	0.65		
		Total	100.18

It appears from this that it is the dense variety of pyrophyllite, $Al_2O_34SiO_2H_2O$, known under the various names as agalmatolith, pagodite, and Chinese soapstone. Similar material comes on the market from China in the form of well known Chinese soapstone structures.[1] No reliable information is available about the occurrence of this stone in China as it appears to be far off any line of communication. There are other deposits known in Hungary, Saxony, and Scotland, but they appear to be of no commercial value.

I am under the impression that the mine found in Brazil is the first one in the world that is commercially explorable on a large scale, being right above a railway station and easily accessible. It has been worked as a quarry for building stone, monuments, etc. A minimum estimate of the quantity available is 1,000,000 cubic yards, but probably a closer examination would reveal much more.

The stone can be worked as easily as soapstone or steatite with tools like those used for wood: saws, drills, and on the lathe. After being fired at about 1100°C the stone becomes harder than steel. There is a slight increase in volume to be observed after the firing. The linear expansion may vary between 1 and 3% and this depends on the speed of heating up, principally between 700 and 800°, where the main quantity of water is driven out. At the same time the stone becomes slightly porous, but not so that it would stick to the tongue.

Properly fired agalmatolith has the following interesting properties: The melting point is near cone 30, but unlike porcelain it softens only very little below this temperature. The thermal conductivity is 10–20% higher and the coefficient of thermal expansion 30% lower than porcelain. That is to say, the material is very little sensitive to sudden variations of temperature. It is very resistant to the action of alkalis and has a great toughness, so that even rivets can be hammered on it. But the most important advantage is that it does not shrink or warp unevenly in kilning.

[1] Dammer-Tietze, Die Nutzbaren Mineralien, II, 378.

Objects can therefore be made from it with more exactness than can be reached with any other ceramic product. Screw-threads cut on it will work perfectly after firing. Plates with absolutly flat surfaces can be made, all things that are manifestly impossible with porcelain.

F. Singer calls particular attention to the value of steatite for the manufacture of ceramic products on account of these and other reasons.[1] But agalmatolith, while having all the advantages of steatite has the additional advantage of a higher melting point, and of being a little harder in the raw state, so that finer pieces with thinner walls, etc., can be turned from it.

Taking into consideration the good qualities of this material it has a great future as a cheaper and better substitute for porcelain and other refractory materials for laboratory, industrial, and household use. The material may be used enameled and uncovered, according to requirements. The mottled surface gives it a distinctly artistic aspect, but the black or yellow specks, due to iron oxide may be hidden if desired under an opaque enamel. The firing requires a lower temperature than in the case of porcelain and is in no way troublesome, as a wide variation in the temperature does not affect the good results. The high percentage of defective pieces which makes first class porcelain so dear, is easily avoided.

Rua Salvador Correa 43
Rio de Janiero, S. A.

NOTES ON VISCOSITY AND DEVITRIFICATION OF GLASS IN FOURCAULT OPERATION[1]

By J. W. Cruikshank

The principal difficulty with the Fourcault operation arises from maintaining the temperature of the glass sufficiently low to obtain the proper viscosity for drawing. The temperature is so low that the ordinary glass from batch similar to plate glass will devitrify, and in order to prevent this sufficient soda has to be added to the batch to overcome the difficulty. When it is stated that the surface of the glass near the debiteuse at the Fourcault factory at Dampremy is 1870°F, and that in contrast to this at the Ford Motor Company the temperature in the canal feeding the rolls is held at approximately 2000°F, it will be seen to what extent it is necessary to reduce the temperature for drawing.

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[1] *Zeits. für angew. Chem.*, **34**, 270 (1921).

[1] Presented at the Annual Meeting, American Ceramic Society, Atlanta, Ga. Feb., 1926. (Glass Division.)

The term "devitrification" is used for a crystallization of the glass mass. Crystals are formed in the glass, or in other words the amorphous form of the mass is changed, and some of the substances form true chemical combinations and crystallize out instead of remaining in solution. The term "solution" is used, as the generally accepted view now held is that glass consists of the various component oxides in mutual solution. The term "mutual" is used to express the idea that one substance is a solvent for another, such as a mixture of water and ether, and ether in water.[1]

Devitrification will take place at varying temperatures in different glasses, depending on the composition of the glass.[2] If the lime content is increased devitrification becomes much more rapid. A glass will devitrify if it is kept in a molten condition for any length of time, but this devitrification ceases at certain temperatures, and even in solid sheets, if kept hot long enough, devitrification will slowly occur. In the following statement the term "velocity" is used for the rapidity of the formation of the crystals of devitrification which varies according to the temperature. For example, assume a glass whose devitrification velocity is a maximum at 2200°F, this velocity will drop off very rapidly as the temperature rises to 2330°F when devitrification presumably ceases. On the other hand the velocity will also fall with a drop in the temperature. This is illustrated in Fig. 1.[3] The problem is to correlate the viscosity[4] with the temperature at which the glass can be held for a reasonable length of time for working purposes without devitrification.

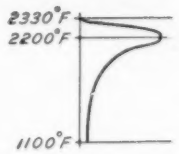

FIG. 1.

On this basis the following is approximately the conditions under which the Fourcault machine is operated. Assume that the temperature, necessary to produce the required viscosity for drawing a sheet under the conditions of those of the Fourcault process, is 1870°F. The glass must be suited to this temperature, so that it will not devitrify at the end of the tank and in the canals where it remains for an appreciable length of time or travels very slowly through them. If the lime content of the glass is raised, the temperature at which devitrification takes place at once falls, and the whole mass will devitrify as it cannot be held at such a low temperature as 1870°F. If the lime is only a little too high compared with the soda, devitrification will not take place

[1] Dralle Vol. 1, p. 7.

[2] Gelstharp and Parkinson, *Trans. Amer. Ceram. Soc.*, **16**, 109 (1914).

[3] Zschimmer, Theory of Glass Melting, Vol. 2, p. 151.

[4] Washburn and Shelton, "The Viscosity of Soda-Lime Glasses," Univ. Ill., *Bull.*, No. 140 (1924).

during perhaps a period of several weeks run, but as the glass practically has no movement in parts of the canals and remains there for some time, it is only a question of time when the devitrification will set in, and trouble commences. It will thus be seen that glass used in this process from the nature of it must be high in alkali and low in lime in order to lower the temperature without danger of devitrification.

This question of devitrification has been gone into at some length, as statements have been made that the troubles in the Fourcault machine are not in the drawing, but in the insufficient provision for annealing in the comparatively short vertical leer. Whereas if the question is thoroughly investigated it will be found to be in the nature of the drawing operation as outlined above.

CRUIKSHANK ENGINEERING CO.
PITTSBURGH, PA.

ACTIVITIES OF THE SOCIETY

NEW MEMBERS RECEIVED FROM JUNE 16 TO JULY 15

Harry T. Brodersen, Box J, Pittsburg, Calif. Chief Chemist, Johns-Manville, Inc.

J. Gavin Callinan, 535 N. Hornor Ave., Clarksburg, W. Va. Chemical Engr., Clarksburg Glass Co.

Oscar Dallons, P. O. Box 1065, Station C, Los Angeles, Calif. Glass Importer.

E. M. DeRemer, 950 S. Broadway, Los Angeles, Calif. Sales Engineer, Southern California Gas Co.

Harry B. Matzen, 923 Union Trust Bldg., Cleveland, Ohio. Manager, Carrier Engineering Corp.

Membership Workers' Record

	Personal
H. H. Blau	1
H. J. Knollman	2
Office	2
Total	5

PERSONAL NOTES OF MEMBERS

D. A. Abrams, formerly in charge of the Structural Materials Research Laboratory, Lewis Institute, Chicago, is now with the Portland Cement Association, 33 W. Grand Ave., Chicago, Illinois.

Vincent Axford has requested that his address be changed from Newcomb College, New Orleans, La., to Knoxville, Tenn., c/o Knox Porcelain Corp.

MacDonald C. Booze, Senior Fellow of the Multiple Industrial Fellowship which is sustained by the American Refractories Institute at Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh, Pa., has resigned to accept a position with the Charles Taylor Sons Co., Cincinnati, Ohio, as vice-president in charge of research and development. Mr. Booze, who has been very active in the refractories industry since 1923, when he became a member of Mellon Institute, has contributed valuably to the knowledge of refractories and their uses.

Herman L. Cook, formerly associated with the Ingram-Richardson Mfg. Co., of Beaver Falls, Pa., is now with the Baltimore Enamel and Novelty Co., of Baltimore, Md.

R. R. Danielson, representative of the Enamel Division on the Board of Trustees of the SOCIETY has moved from Milwaukee, Wis., to 635 Magie Ave., Elizabeth, N. J. Mr. Danielson has recently accepted a position with the Metal and Thermit Corporation, 120 Broadway, New York City, and will spend a considerable portion of his time at the Carteret plant of the Company.

T. A. Klinefelter has requested a change of address from Glendale, California to 120 Maryland Ave. N. E., Washington, D. C.

P. W. Martin, formerly of Macon, Georgia, has removed to 29 Broadway, New York City, c/o Moore and Munger.

Elmer H. Ockerman writes that his present address is c/o Alhambra Kilns, Alhambra, Calif.

Ralph J. Paddock, who received his Master's degree from Ohio State University in June and held a co-operative Fellowship with the U. S. Bureau of Mines, has accepted a position with the U. S. Gypsum Company and is located at 313 East Second St., Port Clinton, Ohio.

Stuart M. Phelps, who has been employed on the Refractories Fellowship at Mellon Institute since 1913, has been appointed director of research of the American Refractories Institute, effective July 1, 1926. Mr. Phelps will have charge of the investigational and testing activities of the Fellowship.

F. H. Norton, Research Fellow of the Babcock & Wilcox Co., East Liverpool, Ohio, can now be addressed at the Department of Physics, Massachusetts Institute of Technology, Cambridge, Mass.

F. G. Roberts is now located at 306 Park Ave., c/o Triangle Sporting Goods, Baltimore, Md.

Louis J. Trostel, Secretary of the Refractories Division of the SOCIETY, has been transferred from the Rockdale Works of the General Refractories Co., at Joliet, Illinois, to the Research and Testing Laboratory of the same Company, located at Baltimore, Md., Box 935.

Bruce F. Wagner, who has been employed with the Coonley Mfg. Co., Cicero, Ill., has accepted a position with the Emerson Brantingham Co. at Rockford, Ill. This Company is starting up an enamel shop to specialize in enameling of refrigerator linings. Mr. Wagner can be addressed at 850 Haskell Ave., Rockford, Ill.

J. W. Wenning, Superintendent and Vice President of the Vitro Mfg. Co., has removed from 3313 Allendale St., Pittsburgh to 607 Clearview Ave., Crafton, Pa.

Edward P. Wright has moved from Irwin, Ill. to 203 W. 5th St., East Liverpool. Ohio.

J. W. Wright has recently accepted a position as salesman of special clays for the Laclede-Christy Clay Products Co. and can be addressed to that Company, 1674 Railway Exchange Bldg., St. Louis, Mo.

Wilbur Wyckoff, who has been connected with the ceramic department at Rutgers University, is now working for the M. D. Valentine & Bros. Co., Woodbridge, N. J.

STANDARDS COMMITTEE OF ENAMEL DIVISION MEETS

Members of the Enamel Division will be interested to know that in connection with the recent meeting of the Advisory Committee of the Bureau of Standards in Washington, the Standards Committee of the Enamel Division spent one entire day going over the affairs of the Committee. Those who were present were H. G. Wolfram, Bureau of Standards; R. D. Cooke, Columbian Stamping and Enameling Co.; W. D. Harrison, Bureau of Standards; and E. P. Poste, Chattanooga Stamping and Enameling Co.

The work which the Committee completed last year was reviewed, including a discussion of the questionnaires sent out to the Enamel Division. Plans for this year's work were made, looking forward to carrying out the uncompleted problems started last year and the undertaking of several new items.

Local Section Changes Name

The Michigan-Northwestern Ohio Section of the AMERICAN CERAMIC SOCIETY recently met in Detroit. Officers for the Section are A. P. Ball, Chairman, Square D Company, Detroit, Mich., and W. A. Carter, Secretary and Treasurer, the Detroit Edison Co., Detroit, Mich.

NOTES AND NEWS

DR. HOLMES TO HEAD NEW CERAMIC SCHOOL

M. E. Holmes of Columbus, Ohio, was appointed head of the new department of ceramic engineering of the School of Mines and Metallurgy, at the meeting of the board of curators held in St. Louis last week. The new course will be opened for registration this coming fall.

Dr. Holmes is a graduate of the University of Indiana and of Cornell University. He has been connected with the ceramic industry for several years. He was for some time chemical director of the National Lime Association and for a while acting general manager of this organization. During the past three years he has been connected with the Ceramic Experiment Station of the United States Bureau of Mines at Columbus, Ohio, doing research in connection with the ceramic industry. He is a member of the AMERICAN CERAMIC SOCIETY, the Cosmos Club of Washington, the American Institute of Chemical Engineers, The American Chemical Society, and Sigma Xi fraternity.

M. E. HOLMES

The new course in ceramic engineering was established by the School of Mines and Metallurgy at the request of the clay industries of Missouri. The ceramic industry in Missouri now ranks next to lead in point of value in the mineral industry of the state, and is growing rapidly. Missouri ranks third among the states as a producer of clay products. The clay people have for several years felt that they were entitled to technical aid within the state for this important industry.

As a means of interesting students in the new ceramic course the Clay Industries Association has voted three scholarships of $100 each to be awarded to students enrolling in the ceramic course next fall.

PACIFIC-NORTHWEST CLAYWORKERS ASSOCIATION

Members of the Pacific Northwest Clayworkers Association held a successful meeting at Vancouver, B. C., July 16 and 17. A visit was made to the Clayburn and Kilgard plants, the largest in British Columbia.

On Saturday a technical session was held at the Elysium Hotel with the following papers presented:

1. "Description of New Brown Recording Carbon Dioxide Apparatus for Kiln Testing" by H. N. Baumann, Jr.
2. "Preliminary Results of Freezing Tests of Local Brick" by F. N. Woodward.
3. "Progress Report of Efflorescence Tests of Various Mortars and Brick Panels" by Hewitt Wilson.
4. "Progress Report of Heat Balance of Continuous Kilns" by H. N. Baumann, Jr.
5. "Effect of Addition of Common Salt to Glacial Clays" by Hewitt Wilson.
6. "Comparison of Laboratory and Commercial Kilns Tests" by Kenneth Johnson.
7. "Brick as a Building Material—Factors Affecting Its Strength—Summary of Test Data" by W. J. Howard.

SOCIETY OF GLASS TECHNOLOGY

The last meetings of the Society of Glass Technology for the session 1925–26 were held in London, June 1 and 2, 1926. President Walter Butterworth presided at the June 1 meeting held in University College when a lecture and demonstration on "Glass in Early Ages" was given by W. N. Flinders Petrie. This meeting was attended by some of the touring members of the Stained Glass Association of America.

Prof. Flinders Petrie said that in his opinion no glass was made in Egypt prior to about 1500 B. C., all earlier specimens being imported. There was no question that the Syrians were far ahead of the Egyptians up to this period in the matter of art and industry, and one had little difficulty in attributing to the Syrians the glasswares which were imported into Egypt prior to 1500 B. C., Examples of glass had been found in Syria, in the Euphrates region, which could definitely be dated back to 2500 B. C. It was significant that only 50 years or so elapsed between a time when glass was a comparatively rare commodity in Egypt and a time when it was possibly the commonest commodity of all. Glass vases and glass beads rapidly came into everyday use. At first it was not a liquid glass which was produced, but a glass paste which could be molded in the plastic state. No blown glass was found in Egypt until one came to an examination of the products of the Christian period. The aim of the early Egyptians was to produce something which would emulate precious stones. For this it was necessary to obtain the right color, and the whole of the earliest glasswares discovered in Egypt was colored.

It was not until about 1200 B. C. that the Egyptians began to make glass by pressing it into molds, and from thence onwards, until the 7th century B. C., the color of their glasswares appeared to get worse and worse, although the patterns became more and more composite. It was not until after the Roman period that the problem was tackled of painting glass by the application of colors to the surface. From the year 350 A. D. the Egyptian glassmakers resorted to the molding of glass in the production of standard weight for gold coins, a practice which was later copied by the Arabs and which led to the development of a remarkable system of weights. About 780 A. D. there was a sudden outburst of accuracy in the production of weights, and 3 examples of glass weights had been excavated which agreed to within a 200th of a grain.

The application of a glass or glaze to other materials was then discussed. The glazing of stones appeared to have been begun in Egypt about the 12th century B. C., and the Egyptians early learned the lesson that they must, at all costs, keep iron out of their glazes or else their colors would be lost. Some of the tiles covering the walls of early Egyptian chambers were magnificent examples of coloring. Not only single colors were achieved, but also polychromes.

In conclusion, the lecturer remarked that he was of the opinion that a good deal more knowledge of the history of glass might become available when Asia was really opened up for proper investigation and study. Not until then might one really get to know, for the first time, what was the actual origin of glassmaking.

On the evening of June 1, the annual dinner of the Society was held in the Hotel Cecil. The guests included Edward Manville (Master of the Glaziers' Company); Alex. L. Howard (Master of the Glass Sellers' Company); and sixteen touring members of the Stained Glass Association of America.

During the morning of June 2 members of the Society had the privilege of visiting the Osram G.E.C. Glass Works and the Research Laboratories of the General Electric Co., Ltd., at Wembley. Lunch and tea were kindly provided and a general meeting was held in the afternoon in the Library of the Research Laboratories. At this meeting the following papers were presented:

(*a*) "Opal Glass", by J. W. Ryde. This was a communication from the Research Laboratories of the General Electric Co., Ltd. Opal glasses could be divided into two

groups: those which obscured a source of light placed behind them, and those through which a red image of the source was visible, the glass itself appearing bluish. The causes of opalescence were reviewed.

A number of commercial and experimental glasses were examined by the X-ray method in order to determine the nature of the opacifying material which separated out. From the X-ray patterns obtained it was shown that sodium fluoride and calcium fluoride had separated out from the glasses examined, the lime and soda contents of which were quoted. It was also found that from one glass no X-ray pattern was obtained and the opacity in this case was attributed to the presence of bubbles. In another glass containing very little lime only sodium fluoride was found to have separated out. But as the lime contents of the glasses increased, calcium fluoride separated out in increasing quantities. Slides showed the patterns obtained. Some glasses that were suddenly chilled were almost clear, but had a bluish cast. In these the particles which separated out were very small. The rates of cooling were controlled, and varied so that the effect of the rate of cooling on the depth of opal produced could be investigated. With slow cooling the size of particles which separated out increased until a certain limiting size was reached. The optical properties of opal glasses were next discussed. To demonstrate the influence of opacifying particle size in the transmission of light, standard solutions were prepared which contained very fine white particles in suspension. By means of these solutions the effects of particle size and total mass of particles on the transmission of light were demonstrated. A solution with large particles appeared bright by transmitted light and dark by reflected light. Hence in bulbs made of opals in which the opacifying particles were relatively large, very little light was scattered back to traverse the bulb again.

(*b*) "The Electrical Conductivity of Glasses at High Temperatures." By F. F. S. Bryson. The electrical conductivity of several series of glasses was determined at temperatures between the softening point and 1150°C. The glass was heated in a small cylindrical crucible in a platinum wound electric furnace. A valve generator was used as a source of current, and a bridge method was employed for measuring the resistance between platinum electrodes immersed in the glass. The results showed that a considerable increase in conductivity was obtained when Na_2O was substituted for SiO_2 in a simple soda-silicate glass. In three component glasses the conductivity was increased by the substitutions of MgO for SiO_2; but lowered by the substitutions of Al_2O_3 for SiO_2 or for Na_2O. The temperature-resistance curves for several of the glasses bore a close relationship to the temperature-viscosity curves for similar glasses and suggested the possibility of using conductivity measurements as a method of determining changes in the viscosity of a glass immediately before being worked. An experimental arrangement was described, by means of which a record was obtained, on a millivolt recorder of the usual works type, of the variations in the conductivity of the glass flowing along the channel leading from the tank to a bottle-making machine.

(*c*) "The Influence of Moisture on the Rate of Melting and on the Properties of Soda-Lime Glasses." By Edith M. Firth, F. W. Hodkin, M. Parkin, and W. E. S. Turner. This paper was presented by Prof. Turner who reported the results of experiments with 4 series of meltings, in 2 of which soda was introduced wholly as soda ash, in the other 2 partly as saltcake. Moisture was present in amounts ranging from 0.25 to 15% in different batches. In general, the presence of a limited amount of moisture had a beneficial effect on the rate of melting. In the case of batches containing no saltcake the best amount appeared to be about 1% and exceeding 2%; for batches containing saltcake, 3 to 4%. The glasses made from batches containing saltcake were refined more easily and were freer from waviness than those prepared from batches containing soda ash only. Glasses prepared from batches containing more than a certain proportion of moisture were found to be more viscous and to have a shorter working range than those obtained from ordinary dry batches.

CALENDAR OF CONVENTIONS

AMERICAN CERAMIC SOCIETY		
Summer Meeting	Aug. 30–Sept. 2, 1926	Philadelphia, Pa.
Annual Meeting	Feb. 14–19, 1927	Detroit, Mich.
Amer. Assn. Advancement of Sci.	Dec. 27, 1926–Jan. 1, 1927	Philadelphia, Pa.
Amer. Chemical Society	Sept. 6–11, 1926	Philadelphia, Pa.
Amer. Electrochemical Society	Oct. 7–9, 1926	Washington, D. C.
Amer. Engineering Council	Jan. 1927	Washington, D. C.
Amer. Foundrymen's Assn.	Sept. 27, 1926	Detroit, Mich.
Amer. Gas Assn.	Oct. 11–14, 1926	Atlantic City, N. J.
Amer. Institute	Oct. 18–30, 1926	New York City
Amer. Inst. Min. and Met. (General Meeting)	Oct. 6–9, 1926	Pittsburgh, Pa.
Amer. Inst. Min. and Met. Engrs. (Annual Meeting)	Feb. 14–17, 1927	New York City
Amer. Mining Congress	Dec. 1926	Washington, D. C.
Amer. Soc. Mech. Engrs.	Sept. 27–30, 1926	Richmond, Va.
Amer. Soc. for Steel Treating	Sept. 20–24, 1926	Chicago, Ill.
Assn. Sci. App. Makers	April, 1927	?
Congress of Amer. Industry	Sept. 7–24, 1926	Philadelphia, Pa.
English Ceramic Society	Sept. 16–17, 1926	Leeds, England
Glass Container Assn.	April or May, 1927	?
The Gypsum Industries	Dec. 1926	Chicago, Ill.
Hollow Building Tile Asssn.	Feb. 1927	Chicago, Ill.
Natl. Assn. of Mfrs.	Oct. 20–22, 1926	New York City
Natl. Assn. of Mfrs. of Pressed and Blown Glassware	March 8, 1927	Pittsburgh, Pa.
Natl. Expostion of Power and Mech. Eng.	Dec. 6–11, 1926	New York City
The Natural Gas Assn. of Amer.	May, 1927	Cincinnati, Ohio
Natl. Safety Council	Oct. 4–9, 1926	Detroit, Mich.
Ohio Ceramic Industries Assn.	Oct., 1926	Columbus, Ohio
Optical Society of America	Oct. 21–23, 1926	Philadelphia, Pa.
Society of Glass Technology (Eng.)	Oct. 20, 1926	Sheffield, England
	Nov. 17, 1926	Leeds, England
	Dec. 15, 1926	London, England
Stained Glass Assn. of Amer.	June 27, 1927	St. Louis, Mo.
Taylor Society	Dec. 8–11, 1926	New York City

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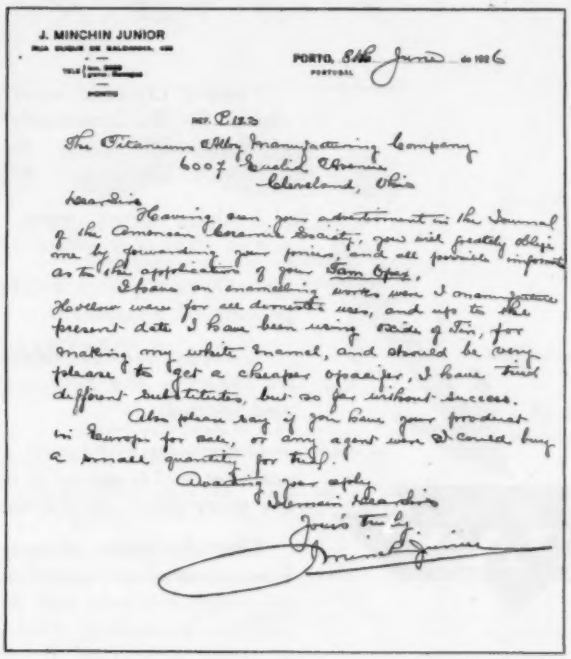

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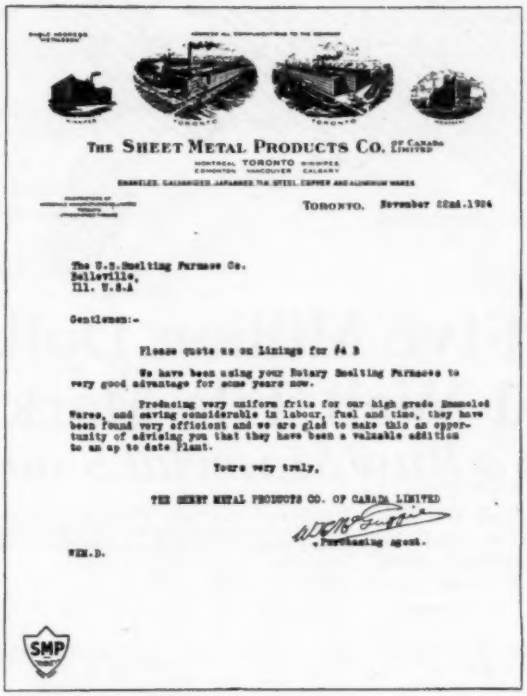

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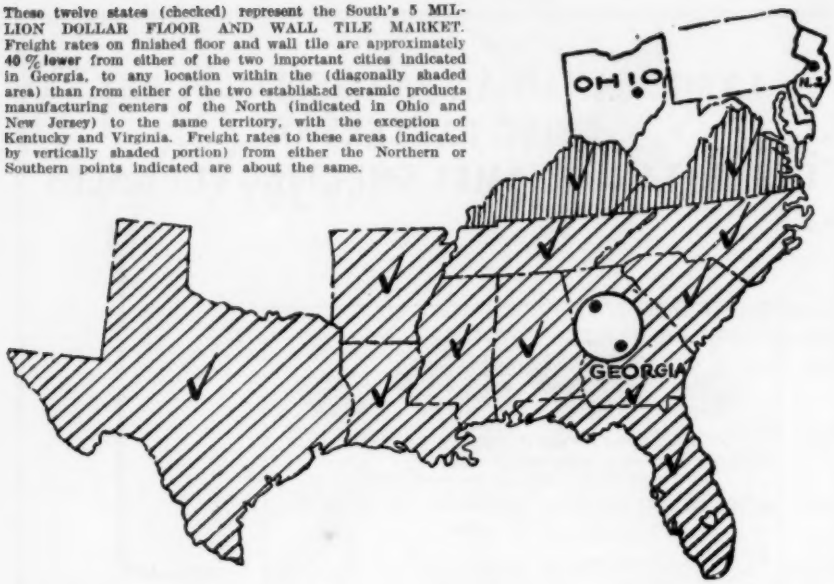
These twelve states (checked) represent the South's 5 MILLION DOLLAR FLOOR AND WALL TILE MARKET. Freight rates on finished floor and wall tile are approximately 40 % lower from either of the two important cities indicated in Georgia, to any location within the (diagonally shaded area) than from either of the two established ceramic products manufacturing centers of the North (indicated in Ohio and New Jersey) to the same territory, with the exception of Kentucky and Virginia. Freight rates to these areas (indicated by vertically shaded portion) from either the Northern or Southern points indicated are about the same.



Here's a Five Million Dollar Floor and Wall Tile Market
that is also a Raw Material Source

yet 95% of its Floor and Wall Tile consumption is supplied from Northern ceramic products manufacturing centers, that *draw their raw materials from within the very territory of this extensive market!*

Consider for a minute the excessive raw material assemblage cost and distribution of finished product cost, of Northern Floor and Wall Tile manufacturers selling in this Southern market! There is the long-haul of raw materials to Northern points and likewise the return long-haul of finished products to distribution centers of the South! It is hardly conceivable in the face of this worthwhile and expanding market, that at present there are no Floor and Wall Tile plants of any consequence in the South serving the South—yet it is a fact!

The branch plant of a Northern Floor and Wall Tile manufacturer, located in Georgia on the above map, would enjoy a *40% lower material assemblage and distribution cost* in serving the Southern market! From the states checked above every raw material for high grade Floor and Wall Tile manufacture is available in abundance.

Decentralize your operations—establish a branch plant in Georgia and serve the Southern Floor and Wall Tile market to greater advantage than it is possible from either of the Northern ceramic products manufacturing centers!

Ask us to give you the facts. Our Industrial Department has compiled considerable up-to-date and valuable information concerning the opportunities for establishing Floor and Wall Tile manufacturers, in Georgia.
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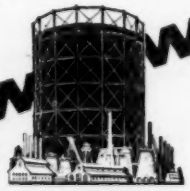

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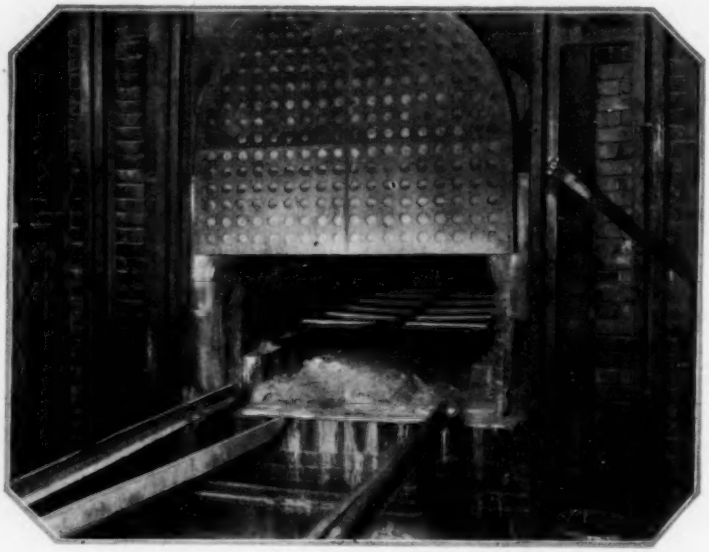

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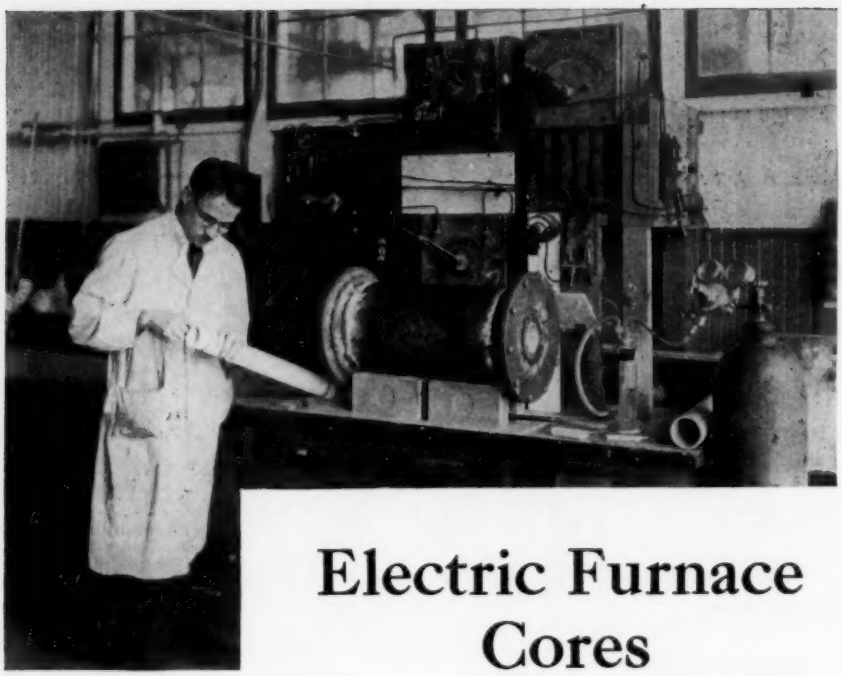

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The fundamental requirements of electric furnaces are *strength, heat conductivity* and *electrical resistance.*

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> "Wire and Ribbon Wound Resistance Furnaces" by Prof. Charles C. Bidwell. May, 1926, issue of "Journal of the Optical Society of America and Review of Scientific Instruments."

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Norton Co.

Slabs (Furnace)
The Carborundum Co.
Norton Co.
Parker Russell Co.

Smelters
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Parker Russell Co.
The Massillon Refractories Co. *("Alumite")*
U. S. Smelting Furnace Co.

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Harshaw, Fuller & Goodwin Co.
Innis, Speiden & Co.
Roessler and Hasslacher Chemical Co.

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Metal & Thermit Corporation
Vitro Mfg. Co.
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Sodium Fluoride
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Pennsylvania Pulverizing Co.
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Potters Supply Co.

Stacks
Lancaster Iron Works, Inc.

Stilts
Potters Supply Co.

Sulphuric Acid
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Harshaw, Fuller and Goodwin Co.
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T

Talc
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Parker Russell Co.

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Mueller Machine Co., Inc.

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Titanium Alloy Mfg. Co.

Tubes (Insulating)
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McDanel Refractory Porcelain Co.
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Pure English Cornwall Stone	Eureka #1 Feldspar
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Eureka Specially Selected Glaze Spar has been famous for Twenty Years for its Brilliant Lustre

EUREKA FLINT & SPAR CO.
Trenton – New Jersey

Suppose all we young fellows swore off shaving for life—what a fine looking race we'd be. But you have got to hand it to whiskers, they are the nearest thing to perpetual motion we have, month in and month out—never failing us for even a day.

A lot of Ceramic manufacturers feel the same way about

EDGAR CLAYS

using them year after year because they are assured of QUALITY, UNIFORMITY and PRICE. Another thing, they are always as represented.

DON'T take our word for it—
but first look at all the advertisements—
Then turn to page 3 and read that letter.
You will better understand our message on page 37.
Need more be said?

AMERICAN CERAMIC SOCIETY
2525 N. High Street Columbus, Ohio

BUYERS' GUIDE (continued)

V

Vacuum Pumps
Mueller Machine Co., Inc.

W

Wad Mills
Cain Machine Co.

Wet Enamel
Chicago Vitreous Enamel Product Co.
The Porcelain Enamel & Mfg. Co.
Vitro Mfg. Co.

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Witherite
Harshaw, Fuller & Goodwin Co.
Innis, Speiden & Co.

Z

Zirconia
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CLAY
H. C. SPINKS CLAY CO.
NEWPORT, KY.
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Write for samples

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for all Clay Products

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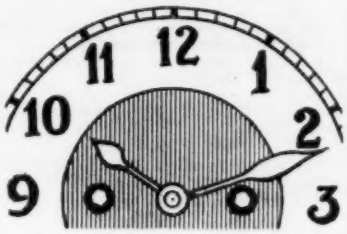

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Our Prompt Service

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SAGGER ROOM	SLIP HOUSE	GRINDING ROOM
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THE MUELLER MACHINE CO.
TRENTON, N. J.

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THE SHARP-SCHURTZ CO.
Chemists for the Ceramic Industry
We have fully equipped laboratories at Lancaster, Ohio, U. S. A.

T. W. GARVE
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Twenty Years' Experience in the Clay Industries
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Design, Construction, Operation, Efficiency

You can use this space to advantage

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2525 N. High Street
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CERAMIC BREVITIES

The Bastian-Blessing Co., 240 E. Ontario St., Chicago, Ill., manufacturers of the well-known Rego oxy-acetylene regulators, torches, etc., have issued a very interesting catalog which is replete with descriptions of their product.

Recent tests of their type "P" generator by the Underwriters' Laboratories have shown that this type will operate under the most trying circumstances.

Ceramic plants using equipment of this nature will do well to write for their catalogs and prices since they have apparently spared no expense to make their equipment safe and dependable.

The general offices of the Hydraulic Press Mfg. Co. will shortly be moved from Mt. Gilead, Ohio, to Columbus, Ohio.

THE PARKER RUSSELL CO.
ST. LOUIS

BUILDERS OF
RO-MACK Enameling Furnaces
HIGH TEMPERATURE FURNACES
For all Purposes

HIGH GRADE REFRACTORIES

TRADE MARK
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McDanel Refractory Porcelain Company
Beaver Falls, Pennsylvania

UNUSUAL · SHAPES · OUR · SPECIALTY

HIGH GRADE
CLAYS
OF EVERY KIND—FOR EVERY PURPOSE
UNITED CLAY MINES CORPORATION TRENTON, N. J.

Continuous Tunnel Kilns Vitreous Enameling Furnaces
HOLCROFT & CO.
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We are manufacturers of
POTTERY and CERAMIC
machinery
Please let us know your requirements
The Cain Machine Co. East Liverpool, Ohio

USE "HY-GRADE" MANGANESE
for surface and body coloring. We pay special attention to our 200 mesh powder that will not "Cat Eye" in glazes.
We mine and very carefully prepare every pound of our own product.
HY-GRADE MANGANESE COMPANY, Inc.
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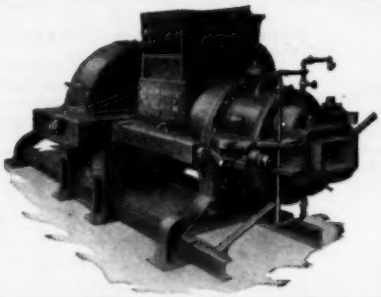
If you want pyrometer protection tube satisfaction
USE
Montgomery Hard Porcelain Pyrometer Tubes
All Sizes and Lengths for either Platinum or Base Metal Couples
The Best Liked and Most Largely Used
Protection Tubes on the Market today
If the manufacturer of your pyrometer equipment cannot supply you, write us direct.
TRADE MARK
MONTGOMERY PORCELAIN PRODUCTS CO.
FRANKLIN, OHIO, U. S. A. 10-22

Brick Making Machines
Crushers Grinders Mixers
Automatic Cutters
Chambers Bros. Co.
Philadelphia Pennsylvania



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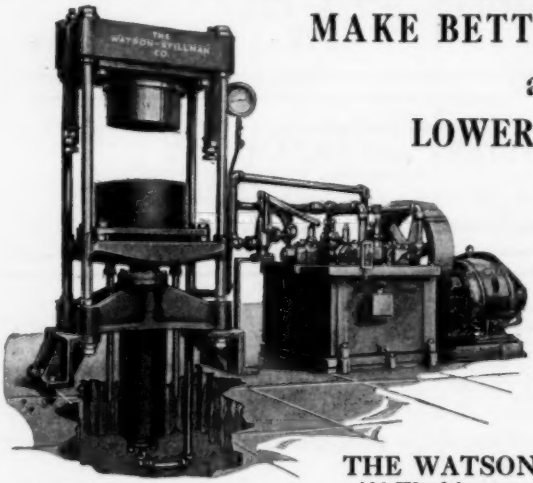
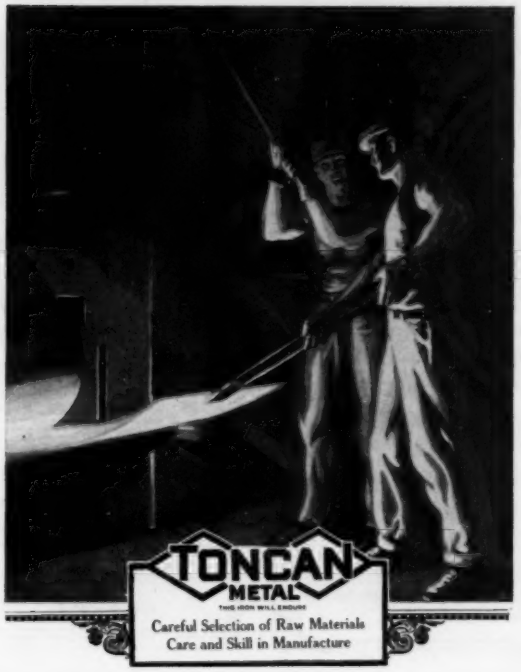


Showing a 50 Ton Sagger Press Outfit Completely equipped with dies for making Elliptical Saggers.

These Machines press saggers from solid wads of clay. Our sagger dies have no joints to work loose or open under pressure; this insures a homogeneous product and reduces to a minimum the losses in firing.
Write for Bulletins and full information
THE WATSON-STILLMAN CO.
108 Washington Street, NEW YORK
Chicago, 549 Washington Blvd.
Philadelphia, Widener Bldg.
Cleveland, Auditorium Garage Bldg.
Detroit, 7752 DuBoise St.



Reduces Seconds

Speeds Up Production

Exceptional Experience Serves You Best

THE makers of Toncan Enameling Sheets possess exceptional sheet mill experience. Their knowledge of enameling requirements is the result of a business lifetime devoted to the production of a uniform quality enameling metal.

Unusual care must be used to prevent distortion of the sheets in the rolling of Toncan Enameling Stock. Exceptional skill is required to hinder the tendency of sheets to glaze under the action of the rolls and thus preserve a slightly open surface to which the enamel will become firmly adherent.

The rolling process is only one of the many steps in the production of Toncan Enameling Sheets. Throughout the annealing, pickling and cleaning processes this same painstaking care is exercised. It is only natural that enamelers who use Toncan report an unusually uniform quality—the result of exceptional skill in sheet production which experience alone can perfect.

Write for samples of Toncan and test it with the metal you are now using. Then you will know what an enameling base can and should do for you.

UNITED ALLOY STEEL CORPORATION, CANTON, O.

Portland
Indianapolis
San Francisco
Chicago
Detroit
Pittsburgh
Philadelphia
New York
Syracuse
Cleveland

TONCAN ENAMELING SHEETS

Since 1869

Alsing Service

Alsing Service represents the modern way of lining a Pebble Mill—scientific and practical advances, including a Porcelain Brick Lining that fits in your Pebble Mill without the necessary cutting which has been the common practice for years.

Permit us to explain our method by telling us the inside measurements of Mill requiring relining.

J. R. ALSING ENGINEERING CO.
50 CHURCH STREET
NEW YORK CITY

KERAMOS *says*

"If you are interested in Muffles, Furnaces, and their performance, Be sure to read the September issue of the JOURNAL"

The Vitro Manufacturing Company

Pittsburgh, Pa.

Solicits Your Orders for:

ENAMELS (for steel and cast iron)
COLORING OXIDES (for enamels, glass and pottery)
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GLASS MAKERS CHEMICALS
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QUALITY AND UNIFORMITY GUARANTEED

THE VITRO MFG. CO. TRADE MARK PITTSBURG, PA.

Look for Our Trade Mark on Package

W. N. BEST Oil Burners fire the kilns at the largest porcelain wash tray plant in the world.

Write for catalogs and list of users in the Ceramic field

W. N. BEST Corporation
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1816 CHEMICALS 1926

"Over a Century of Service and Progress"

South Dakota
FELDSPAR

An extremely high-grade Potash Spar ground in our own mills under constant and thorough chemical control.

Capacity up to 300 Tons Daily

We solicit your inquiries

INNIS, SPEIDEN & CO., Inc.
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Pure Canadian Potash Feldspar
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SALES OFFICE
323 Fourth Avenue
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THE CERAMIC INDUSTRY'S BEST ASSET

BUILT RIGHT
RUN RIGHT
FOR CLAY WORKERS

The best Asset of the Ceramic Industry is quality of product and quality of product is largely dependent on properly prepared Materials. The American Wet Grinding Pan does its work thoroughly, quickly and cheaply.

This is an unusually well built, dependable unit. Long on service. Light on power. Ask for Bulletin.

We build a complete line of machinery for Ceramic needs.

The Hadfield-Penfield Steel Co.
BUCYRUS, OHIO

A New Ceramic-Refractory Raw Material & Process

(United States Patents 1,585,826 and 1,585,827, May 25th, 1926. Other Applications Pending. Also for refractories, U. S. Patent 1,533,689, April 14th, 1925)

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INTRODUCING:—

HALLE FIRECLAY-SAGGER BODIES KAOLIN-WHITEWARE BODIES

Two world famous clays on the market over 100 years. Quality and uniformity a real fact. A sample will convince you.

ENTERPRISE WHITE CLAY CO.
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WABIK METAL
QUALITY M PRODUCTS

After an exhaustive study of the requirements of the Enameling Industry we are producing:

WABIK METAL
SPECIAL VITREOUS ENAMELING SHEETS

Unlike ordinary steel sheets, warping and blistering is reduced to a minimum, thus increasing the Enameler's output and profit.

Many of the leading plants now recognize "WABIK METAL" as the supreme stock for that beautiful permanent lustre which is so essential in Table Tops, Stove Parts, Refrigerator Parts, Signs, etc.

THE MANSFIELD SHEET & TIN PLATE CO.
MANSFIELD, OHIO

THREE ELEPHANT BORAX
99.5% PURE

Its uniform high quality guarantees the excellence of your product.

We also make Boric Acid Guaranteed 95% pure. Write for our price and samples today.

AMERICAN TRONA CORPORATION
Woolworth Building, New York, N. Y.

Quality *Uniformity* *Service*

LUSTERLITE ENAMELS
MANUFACTURERS

FURNACES - - SPEED FORKS - - ENAMELS
Complete Enamel Shop Supplies and Equipment
STOCK CARRIED

Chicago Vitreous Enamel Product Company
1407-47 S. 55th Court, Cicero, Ill., U. S. A.

Tapping a heat at ARMCO

Plunging, molten, purer iron —and it's virtually degasified

IF YOU could see ARMCO Ingot Iron in the making, it would be readily apparent why this purer iron is so superior for porcelain enameling purposes.

From the open hearth furnace—where ARMCO Ingot Iron is practically freed from harmful gases—to the final rolling and finishing, nothing is left undone to insure uniformity and consistency of quality.

So enamelers use this purer, virtually degasified sheet iron. And day in and day out it gives them the results they're constantly striving for; low cull loss, a finished product that's easier to sell—and bigger profits.

Others are getting these results—you can, too. Ask Dept. D at the address below to tell you just how it's done.

THE
AMERICAN ROLLING MILL CO.
MIDDLETOWN, OHIO

EXPORT:
The ARMCO International Corp.
Cable Address: Armco, Middletown

ARMCO INGOT IRON
The Purest Iron Made

LANCASTER

Other Lancaster Products

AutoBrik Machine
AutoClay Cleaner
Granulators
Disintegrators
Crushers
Steam Pipe Rack Brick Dryers
Cable Conveyors
Winding Drums
Belt Conveyors
Brick Moulds
Clay Storage Systems
Clay Cars
Kiln Castings
Tanks and Stacks
Portable Motor Driven Repress

An Aid to Continuous Production

An old saying runs: "To save time is to lengthen life." In brick plants and in the manufacture of heavy clay products, Lancaster Pug Mills save time and increase profits by assuring continuous production.

When you install a Lancaster Pug Mill, you know that at least as far as that unit in your production is concerned, there will be no costly interruptions and your clay products will always be right. This dependability is built in by careful methods of manufacture and by the choice of fine material. In a Lancaster product you purchase a machine which does its work better and without interruption and whose final cost is very low.

If you plan changes in production methods, Lancaster Engineers can co-operate with you intelligently in furthering your ideas. Call on them for their recommendations.

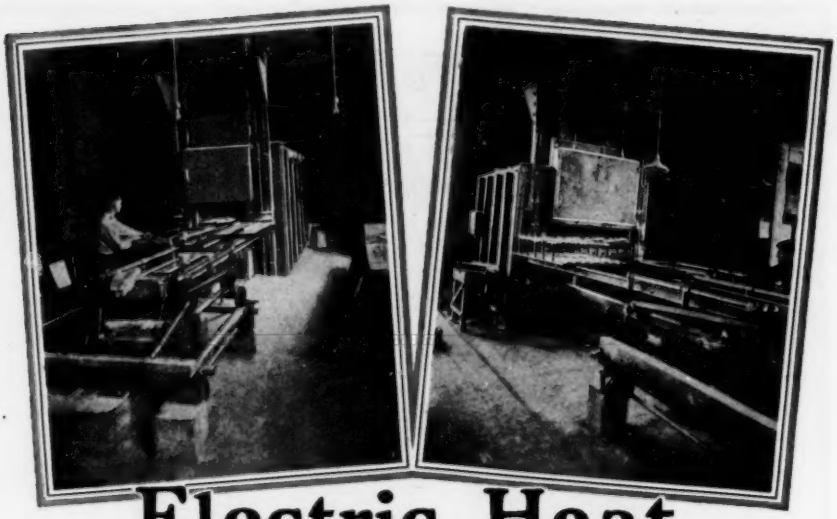
LANCASTER IRON WORKS, Inc.
LANCASTER, PENNSYLVANIA
BRICK MACHINERY DEPARTMENT JAMES P. MARTIN, Manager

Send for this new booklet

"MEN AND METHODS"

An interesting new booklet, telling about the future for porcelain enameling, and the most modern methods of enamel making.

The Ferro Enamel Supply Co., Cleveland, Ohio



Electric Heat
fires the enamel on Galusha Stoves

These clean, neat, efficient, noiseless, fumeless, vitreous enameling furnaces, installed at the Galusha Stove Co., Rochester, N. Y., are equipped with G-E electric heating units and G-E automatic control.

Originally this company purchased its enameled parts. Five years ago a trial electric furnace was installed and its success was such that a second was added. These two furnaces now handle the enameling for all the stoves produced.

Electric Heat has made Galusha enameling an exact science. Piece after piece is just right. It cannot fail to be right, for the heating cycles are always exactly duplicated by the vigilant automatic control.

Clean, odorless, sulphur-free Electric Heat is brought up to the required intensity swiftly—is kept at the ideal temperature accurately—is radiated direct to the charge. The metal pieces are enameled rapidly and emerge with a finish which reflects the highest quality. And—the overall cost of the finished product is actually less.

Write to your nearest G-E office for complete information.

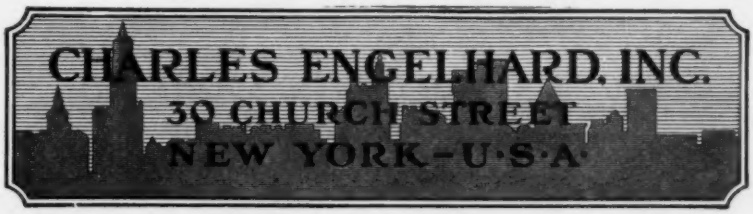
Although electric heat will not supplant all other forms of heat for industrial purposes, there are processes in every industry where it is the ideal heat—the most economical heat—the heat that ultimately will be used.

ULTIMATELY
ELECTRIC HEAT
IN EVERY INDUSTRY

570-13C

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY, SCHENECTADY, NEW YORK



WITH Engelhard Pyrometers paying for themselves on ceramic kilns in from nine months* to a year how much longer can you afford to be without them?

It's a fair question, and in order that you can answer it we suggest that you tell us about your plant and get a quotation on a complete installation of

ENGELHARD PYROMETERS

Full details on request.

Here really IS something to ponder over when deciding how your hard earned advertising money is going to be spent and in what advertising mediums:—

JOURNAL advertising is sold on its merits only—

It is alone in that it does not employ traveling solicitors—

It reaches the man in the plant with whom you want to do business—if you have attended any of the annual meetings you know the type of men we mean.

Figures can be made to show wonderful results and it depends on how they are taken. Consistent growth is much better than spasmodic and the figures below show the increase in JOURNAL advertising for the first six months of the years mentioned. These figures are total pages of NET PAID ADVERTISING exclusive of all classified advertising:

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1925—172.5 pages
1926—178.87 pages

If you think JOURNAL advertising has "stood still" consider then that in 1922 we carried 124.2 pages and in 1923 we carried only 135.8 pages (first six months of each year).

Three short years ago we had a distribution of 2241 copies monthly. Today the distribution is well over the 2500 mark. It's natural for a human being to grow but not so a publication unless there is something worth while between the covers. The JOURNAL has that "something." May we serve you as well as our other 52 advertisers?

AMERICAN CERAMIC SOCIETY
Advertising Department
2525 N. HIGH STREET COLUMBUS, OHIO

Uniform "HURRICANE" Drying *Saves Operating Cost and More—Much More*

Uniform drying of ceramics will save a fixed amount daily, by shortening the drying time. But that is only a part of the value you receive from the remarkable uniformity of "HURRICANE" Drying. The quality of the product is improved, uniformity of output is made possible. Because of the big benefits possible, we have for years concentrated on dryers of *uniform* performance. Facts supplied on request.

Dryers For All Ceramics

THE PHILADELPHIA DRYING MACHINERY COMPANY

Stokley St. above Westmoreland, Philadelphia, Pa.

Canadian Agents:
Ross Whitehead & Co., Ltd.
Montreal

HURRICANE
Ideal Drying Every Day

New England Agency:
Hurricane Engineering Co.
53 State St., Boston, Mass.

ENGLISH AND DOMESTIC

QUALITY

POTTING

CLAYS

Paper Makers Importing Co., Inc.

EASTON, PENNA.

AGAIN!

Pemco

is selected to equip the largest enameling plant in the Central States....

The Fuller-Warren Co. of Milwaukee, Wis., has decided to erect a porcelain enameling plant. This plant when finished will be one of the largest in the Central States.

The Porcelain Enamel & Mfg. Co. has been selected to furnish the equipment throughout.

That briefly is the story—but the reason why we were chosen makes an interesting business story that should be familiar to all who are interested in Porcelain Enameling.

We'll gladly tell it to you,
Want to hear it_____?

THE PORCELAIN ENAMEL & MFG. CO.

BALTIMORE PEMCO **MARYLAND**

PEMCO SERVICE ASSURES SUCCESS